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The Value of Rockweed (Ascophylum nodosum) as Habitat for Tidepool Fishes

Amy Marie Gullo

THE VALUE OF ROCKWEED (*ASCOPHYLLUM NODOSUM*) AS HABITAT FOR TIDEPOOL FISHES

By

Amy Marie Gullo

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Advisory Committee:

John R. Moring, Professor of Zoology, Advisor

Malcolm L. Hunter, Jr., Professor of Wildlife Resources and Libra Professor of Conservation Biology

Robert L. Vadas, Professor of Botany, Oceanography, and Zoology

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Thesis Advisor: Dr. John R. Moring

An Abstract of the Thesis Presented
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Tidepool fishes are an interesting and commercially valuable guild of fishes that reside in tidepools at low tide. Tidepool fishes of the North Atlantic Coast reside in tidepools only during the late spring to fall months, and are typically juveniles of subtidal adult species. Tidepool fishes on the Pacific Coast of North America have been studied extensively, but species of the North Atlantic Coast have rarely been studied. An important area of study is the use of different tidepool microhabitats by fishes, specifically the use of rockweed (*Ascophyllum nodosum*) fringe, which is present in many tidepools. Rockweed is an algal species that grows extensively on the North Atlantic Coast, and it is important due to the current commercial harvest of rockweed along many shores, including the coast of Maine. The objectives of this study were to document the presence of fish species within the rockweed fringe, and to assess the short-term effects of experimental removal of rockweed fringe.

The study took place along the coast of Maine during the summer of 2001 at three sites: Schoodic Point, Great Wass Island, and Quoddy Head. Fishes and invertebrates were sampled in nine tidepools at each site on three occasions before treatment.

Previously assigned experimental treatments (no removal, half removal (fringe length of 15 cm), or full removal of the rockweed fringe) were then performed. Four sampling periods followed treatment to assess short-term effects on fishes, invertebrates, and physical characteristics of the pool.

At least 5 species of fishes, *Cyclopterus lumpus, Myoxocephalus scorpius, Myoxocephalus aenaeus, Pholis gunnellus,* and *Liparis atlanticus*, utilize rockweed fringe habitat. Experimental results are unclear due to high variation within treatments because of the high variability between individual tidepools. However, rockweed was found to host high numbers of invertebrates commonly preyed upon by tidepool fishes, and thus we assume that the removal of rockweed can have impacts on the food base available to fishes. Physical and behavioral characteristics of these fishes, specifically camouflage and modes of attachment, indicate that these species are well adapted to utilizing the habitat, perhaps as a refuge from predators. Rockweed is a species of algae that is vitally important to marine life, and this study has implications for the regulation of commercial rockweed harvesting.

DEDICATION

This thesis is dedicated, in loving memory, to John Moring.

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Many people have been instrumental in the completion of my thesis work, in providing both insight and support. I would like to thank those that assisted in fieldwork, especially Katherine Fisher. Not only did she work hard, but her constant enthusiasm made the field season a lot of fun. Thanks also to the Fisher family for providing a home away from home for us in Down East Maine.

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And last but definitely not least, thank you to all those who provided mental support through these past two years. To Susan Anderson, who has taken care of business and also been an excellent listener and friend, thanks so much. To the graduate students who helped me through all of my problems, whether academic or other, thanks. And finally, to Edward Gunzelmann, who was always willing to do anything, whether fieldwork, laboratory analysis, or just listening to my problems, to help me succeed in this program. This project was funded by the National Parks Service, the University of Maine, and the United States Geological Survey.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

The guild of tidepool fishes is a diverse group of fish that reside in tidepools during low tide. Tidepool fishes have been studied extensively on the Pacific Coast of North America. These studies include those involving fish physiology (Graham 1970), feeding habits (Yoshiyama 1980, Grossman 1986a), competition (Pfister 1995, 1998), recruitment (Thomson and Lehner 1976, Grossman 1986b, Pfister 1996, Polivka and Chotkowski 1998) and habitat use (Green 1971, Nakamura 1976, Yoshiyama 1981, Norton 1991, Davis 2001), among others. One reason for the high number of studies on the Pacific Coast may be the ease of capture and the fact that these fishes typically are year-round residents of tidepools (Pfister1996). On the Northern Atlantic Coast, tidepool fishes typically only reside in tidepools from the early spring until late fall, most likely due to cold temperatures in the intertidal zone during the winter (Moring 1990). Fishes of rocky tidepools of the North Atlantic have not been studied as extensively.

Examples of studies on the Atlantic Coast include inventory work (Moring 1990), habitat associations (Moring 1989), feeding behaviors (Moring 1989, Ojeda and Dearborn 1991), and developmental biology (Moring 2001). Comparable work has been conducted with fishes along the coast of the Eastern Atlantic Ocean, as they typically consist of some of the same species present on the Atlantic Coast of the United States, including lumpfish, *Cyclopterus lumpus*, shorthorn sculpin *Myoxocephalus scorpius,* and rock gunnel, *Pholis gunnellus* (Goulet et al. 1986). Most research on intertidal fishes in Maine and Canada involves species that move subtidally during low tide, and do not commonly reside in tidepools (Keats 1987, Black and Miller 1991, Rangeley and Kramer

1995a, 1995b, 1998). As a consequence, there is an overall gap of knowledge for this interesting group of tidepool resident fishes along the coast of Maine, USA.

One aspect of tidepool fish ecology that should be addressed is how fishes use the microhabitat of the tidepools in which they reside. Tidepools often consist of an array of potential habitats, including caves, rocks, and diverse marine algal communities. Studies of how tidepool fishes on the coast of Maine associate with habitats are rare, with the exception of Moring (1989), in which he studied food preferences and macroalgal associations of juvenile lumpfish, but not other members of the tidepool fish guild. Other studies involving tidepool resident species from the East Coast and Europe noted associations only at high tide, or subtidally. These include work in Europe showing an association of clingfishes with eelgrasses (Hofrichter and Patzner 2000), and strong associations of lumpfish with floating algal mats of the brown algae, rockweed, *Ascophyllum nodosum* (Davenport and Rees 1993, Ingolfsson 1998).

In North America, studies of intertidal fishes have focused on commercially important incidental tidepool residents (fishes that do not actively reside in tidepools but may be trapped in them at low tide). These include studies of the Atlantic cod, *Gadus morhua,* associating with the brown algae *Desmarestia* (Keats et al. 1987), and juvenile pollock, *Pollachius virens* (Rangeley and Kramer 1995a, 1995b, 1998) associating with *Ascophyllum nodosum*. In these cases, *A. nodosum* was studied as a floating mat or submerged at high tide. At low tide, *A. nodosum* is exposed to the air, and drapes into tidepools, thus forming an edge canopy of weed. This leads to the question: If fish use *Ascophyllum nodosum* as habitat in open waters, could tidepool fishes be using this

habitat during low tide, and if so, could this use have implications for the rockweed harvests now taking place on the coast of Maine?

Commercial harvesting of rockweed is relatively new to the coast of Maine. It began in Nova Scotia in the 1950s and spread to New Brunswick in the mid 1990s (Ugarte and Sharp 2001). *Ascophyllum nodosum* is harvested for many different uses, primarily for alginate, fertilizers, betaines, and animal feed (Wu et al. 1998, Leach et al. 1999, Moller and Smith 1999, Ugarte and Sharp 2001). The Canadian government was cautious in opening this new market for algae, and required numerous impact assessments before issuing harvesting permits (Ugarte and Sharp 2001). In the United States, such precautions have not been taken, and thus far, the only regulation on harvesting is the length of algae the harvester must leave behind (40 cm, or 16 inches, above the rockweed holdfast). However, rockweed may provide vital habitat for some coastal species of fishes, and at the 1999 Global Programme of Action coalition for the Gulf of Maine (GPAC) conference entitled "Gulf of Maine Rockweed: Management in the Face of Scientific Uncertainty", a call was made for research on the importance of rockweed to bird, fish, and invertebrate species (Rangeley and Davies 2000).

Previous studies of rockweed harvesting, conducted in Nova Scotia and Maine, have focused on the effects of harvesting on the rockweed itself (Keser et al. 1981, Ang et al. 1996, Lazo and Chapman 1996), the associated macroinvertebrate communities (Fegley 2001), and eider ducklings (Hamilton 2001). Rockweed exists in tidepools as a fringe, consisting of long intertidal fronds of *A. nodosum*, which drape into the pool from the surrounding area, forming a distinct fringe of floating algae. Only one study has documented a tidepool fish species associating with rockweed (Moring 1989), and no

studies have documented the effect of rockweed harvesting on tidepool fishes. As a consequence, my objectives were to (1) document tidepool fish species that are occupying the rockweed habitat and (2) to determine short-term effects of an experimental removal of rockweed fringe.

MATERIALS AND METHODS

Study Sites

The study took place at three sites along the coast of Maine-- Schoodic Point, Great Wass Island, and Quoddy Head Point (Figure 1), chosen because they contained a number of tidepools that were large enough to contain fish, and had an *Ascophyllum nodosum* fringe. Nine tidepools were chosen at each site with a diverse range of algal compositions and locations in tidal range. The study sites exhibited a diurnal tide cycle, with two low tides each day of approximately equal height (monthly range for low tide 0.46 m to –0.61 m).

Sampling Method

Maps were created of each tidepool, using compass and measuring tape, from which the perimeter and surface area of each pool could be calculated. To document fish use of rockweed, I sampled the tidepools from June 21 to July 24, 2001, and to evaluate treatment effects, from August 4 to September 28, 2001. Sampling effort was standardized to assure a complete sample of habitat without researcher bias. For rockweed fringe sampling, this was done by determining the maximum number of nettings that could be performed on the tidepool with the smallest perimeter without sampling any area more than once. I then calculated the number of nettings for the remainder of the pools using the known perimeters of each. Rockweed was sampled with a rectangular (32cm x 23cm) net designed specifically for capturing species only within

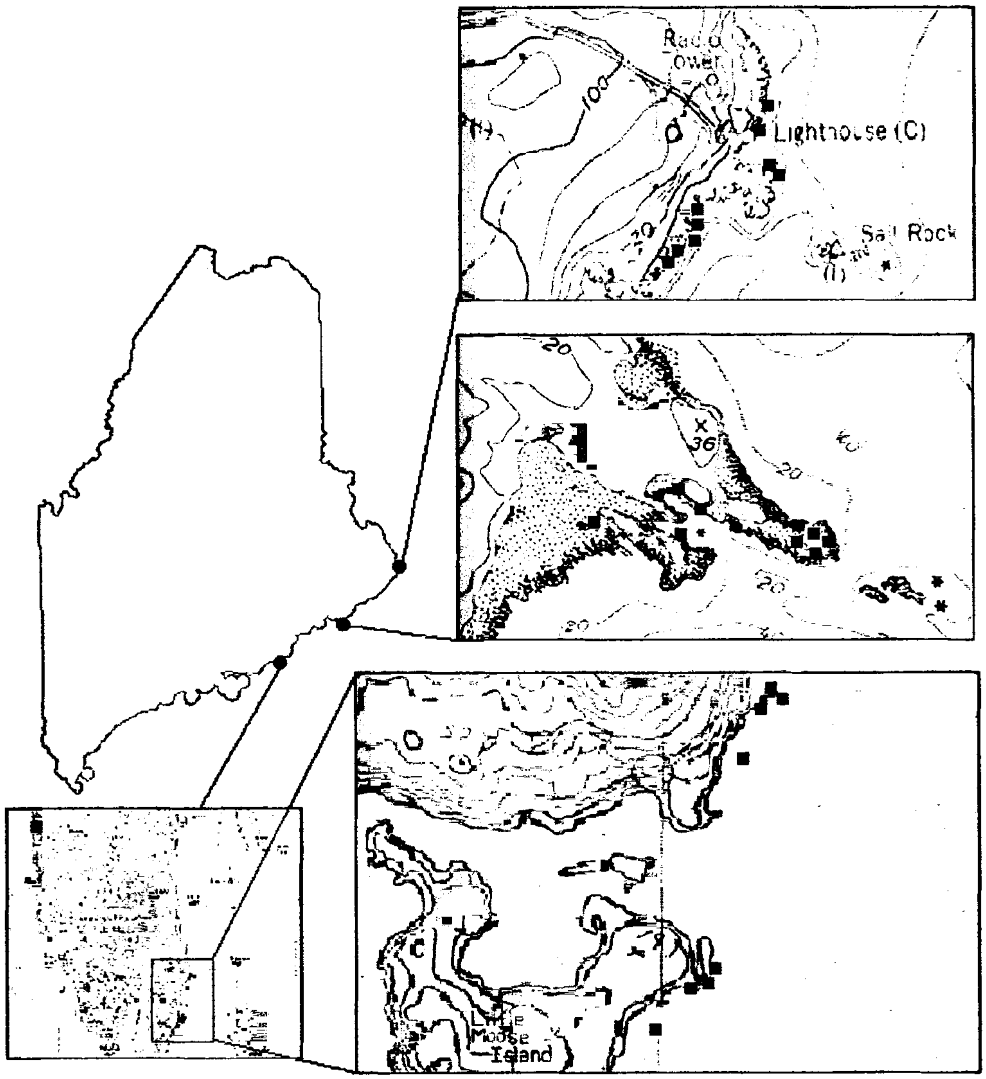


Figure 1: Sites studied along the coast of Maine. Top= Quoddy Head, Middle= Great Wass Island, Bottom = Schoodic Point.

or directly below the rockweed (Figure 2). The net consisted of a wooden frame with a 550-μm mesh fabric that allowed for capture of, not only small fishes, but also small invertebrates that might be consumed by fishes. Tidepool samples were standardized in a similar manner, except this time, I measured the time it took to dip-net the entirety of the tidepool with the largest surface area, and then calculated the time spent dip-netting for the remaining pools from their known surface area.

Tidepools were always sampled in the following manner. First, I noted any changes in algal cover or any visible changes in water quality. Dominant substrate type (brown algae, green algae, or rock) was determined visually by recording any substrate type that was clearly dominating the tidepool (making up approximately 75% or more of the tidepool). If no substrate type could be easily seen as the dominant, the classification "mixed" was given to the pool. Physical characteristics were then measured, including dissolved oxygen, pH, salinity, conductivity and temperature. After physical and biological characteristics of the pool were recorded, I began sampling the rockweed fringe. Rockweed fringe sampling always took place before sampling the remainder of the tidepool, so that the sampling of the tidepool did not scare fish into the rockweed, and hence bias the data. To sample the rockweed, we chose a random location at the edge of the pool and begin sampling the rockweed with the customized net previously described. Each netting involved sitting on the edge of the pool, holding the net with both hands and gently placing the net in the water, just beyond the rockweed fringe. We then quickly swept the net in towards the edge of the pool and upward, to isolate the rockweed fringe while mimicking the sweeping action of a long handled dip-net. Rockweed was then

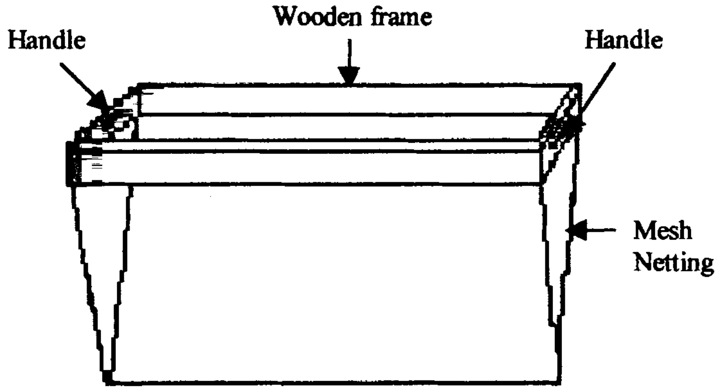


Figure 2: Customized net used to sample rockweed. Dimensions of the net are 32 cm by 23 cm with a depth of 32 cm. Total net volume is 0.05m^3.

shaken in the net, causing fish and invertebrate specimens to drop off into the net. Nets were then emptied into a bucket of fresh seawater. Visible fish were moved to a special fish bucket, to isolate them from invertebrate prey items. This sampling method was repeated for the standard amount of nettings for the pool, moving along the side of the pool to get the most complete sample of the rockweed fringe as possible.

After the rockweed sampling was completed, we began dip-netting the remainder of the tidepool with long handled dip-nets. We began timing as soon as dip-netting was commenced, and only dip-netted the pool for the standardized amount of time. When dip-netting for fishes, the goal was to obtain the most complete sample of the tidepool habitat. When walking throughout the pool, we moved small rocks to disturb hiding fishes. We did not chase fishes, and did not focus on any specific habitat. Using a sweeping motion with the net, we began at the bottom of the pool and worked up the water column. We attempted to sample each area once, emptying the net into another bucket of fresh seawater periodically. Again, if fish were captured they were placed in a separate fish bucket.

When sampling was complete, we removed all large pieces of algae from the samples, being sure to wipe off all visible invertebrates, and placed the algae back in the tidepool. All fish were identified, measured with a fish board, recorded, and returned to the tidepool. Finally, using small mesh nets, we drained the invertebrate samples of all water, and placed the net (with invertebrates) into a whirl pack with 75% ETOH solution, to be brought back to the laboratory for analysis.

Experimental Treatment

To assess the short-term effects of an experimental rockweed fringe removal, tidepools were randomly assigned one of three treatments, no removal, half removal, or full removal of rockweed fringe, before sampling began. Each treatment was repeated three times at each of the three study sites. In order to account for differing lengths of rockweed fringe, a standard half removal was developed for all pools designated as a half removal. The length of the half removal was determined by calculating the average length of the rockweed fringe at one site and dividing the average in half. This resulted in a standard half removal, in which 15 cm of fringe was left intact, to produce a consistent length of algae. Full removal involved cutting the rockweed fringe at the edge of the pool, removing all floating algal fringe. Rockweed cutting occurred in one trip per site at low tide using scissors. Because ocean movement can cause the amount of rockweed hanging into the pools to vary slightly, we swept all surrounding algae into the pool before removal. One week after each treatment was completed, sampling was resumed as before, and four more samples of each pool were taken. This post-cutting experimental segment occurred between August 4 and September 28, 2001.

Statistical Analysis

Statistical analysis was performed using a split-plot ANOVA to assess differences between 3 independent variables: data collected before and after treatment (Before/after), the three treatments (Treatment), and between rockweed and tidepool habitats (RW/Dip). Split-plot analysis was chosen because it uses a second error term (the error within treatments) to account for variability. To control for some of the inherent variation

between tidepools, the analysis included the variable Pool nested with Treatment, (Pool(Treatment)). Nesting of variables allowed me to consider the possibility that all of the pools are not the same for each of the three treatments, so that lack of effect could actually be due to differences within treatments, not between treatments (Zar 1984). Individual hypothesis tests (F-tests) using the output from the split-plot ANOVAs allowed for analysis with a correct error term for each of the three variables, Treatment, Before/after, and RW/Dip, along with the interactions of these variables. Before analysis was performed, the data were transformed in order to account for the high number of values equal to 0, and in the case of invertebrates, to account for the large range of data. To account for the high number of zeros in the fish data, 0.05 was added to each count, then a square root transformation was performed. To account for the large range of numbers in the invertebrates, a natural log transformation was performed (ln(x+1) to account for any zeros in the data set).

Because the rockweed fringe only accounts for a small percentage of the tidepool environment, the same analysis described above was performed for fish and invertebrate data, after the data were standardized for volume sampled. This was done simply by dividing the fish and invertebrate counts by the appropriate estimated volume. The volume of rockweed sampled was estimated by multiplying the number of nettings per tidepool by the volume of the net (0.05 m^3). The volume of the tidepool sampled was estimated by multiplying the known surface area by the estimated depth. Split-plot analysis of variance was performed with this new standardized data exactly as described above.

Finally, a logistic regression model was developed to attempt to predict fish presence in tidepools. This model was chosen because it is useful in interpreting binomial data, and can incorporate both categorical and continuous independent variables (Agresti 1996). In creating the model, I used only data collected after assignment of treatment, samples 4-7, so that I could later add the treatment variable to the model as an independent variable. Two models were developed, one for fish presence in rockweed, and one for fish presence in tidepool habitat, since the factors controlling whether the fishes utilize the rockweed habitat or simply reside in the pool may be different. For my independent variables, I used the factors that varied amongst pools, but stayed relatively constant throughout the sampling season. These included Dominant algae, Surface area, and Depth of each pool. Using these variables, I tested their effect on the binomial dependent variable, Fish presence. Models were developed using the logit function of SYSTAT 10, and goodness of fit was determined using a Pearson's chi squared value (Agresti 1996).

RESULTS

Physical Characteristics of the Tidepools

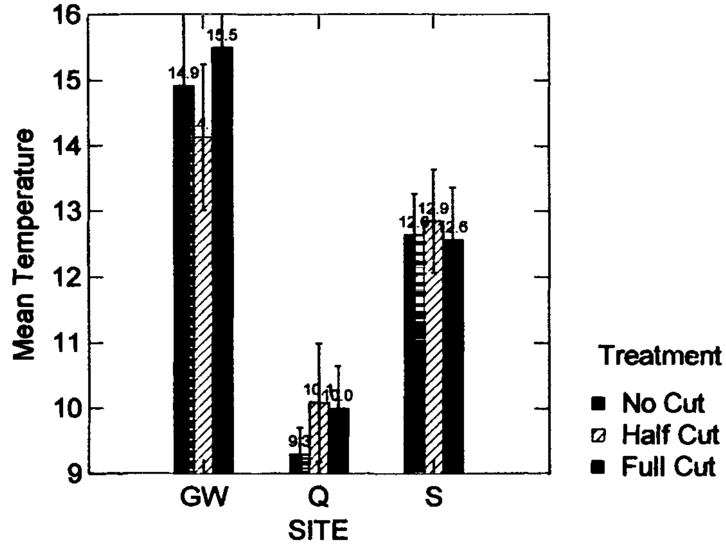
Physical characteristics of each pool have been averaged over each treatment for samples 1-3 (before treatment) and samples 4-7 (after treatment) (Table 1). Most physical characteristics were fairly constant across treatments and sites, including salinity, conductivity and pH. The pH values did increase slightly after treatment, however, these could be due to increased photosynthetic rates of algae in the summer months. The most variable parameters were temperature and dissolved oxygen (Figures 3, 4). Temperature was fairly constant at each site, but a significant difference in temperatures between sites occurred before treatment. After treatment, these temperature differences no longer appear significant, however, this change is more likely seasonal than a result of treatment. Finally, the dissolved oxygen readings tended to be quite variable. Few distinct patterns emerge in terms of treatment and site, and all levels recorded are within the range at which this guild of fish would survive (Kjorsvik et al. 1984, Davenport and Sayer 1993).

Fish and Invertebrate Presence in Pools

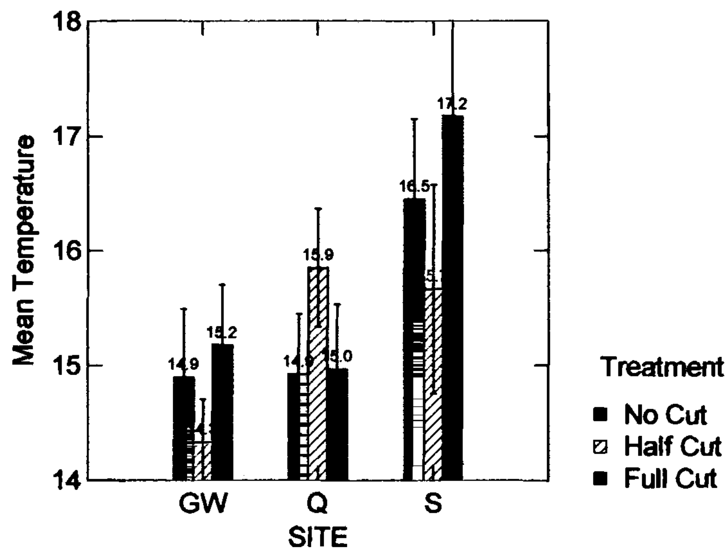
Although the numbers are not high in all situations, fishes were captured in each treatment at each site in both the rockweed and the open pool. This included 420 individuals, and 11 species of fishes, including Atlantic herring, *Clupea harengus,* lumpfish, rock gunnel, shorthorn sculpin, grubby, *Myoxocephalus aenaeus,* Atlantic seasnail, *Liparis atlanticus,* threespine stickleback, *Gasterosteus aculeatus,* pollock, and sand lance, *Ammodytes americanus* (Table 2, Figure 5). One Atlantic cod and one American eel, *Anguilla rostrata*, were captured as well. Lumpfish accounted for the

Table 1: Physical characteristics of each treatment before and after treatment. Values are presented as means for each treatment, with the standard error in parenthesis. S=Schoodic Point, Q=Quoddy Head, GW=Great Wass. R=Rockweed D=Dip-netted in tidepool. Treatments (Trt) are as follows: NC=No cut, HC=Half cut, FC=Full cut.

		Before Treatment					After Treatment				
Site	Trt	Temp (°C)	Salin (ppt)	Cond (ms)	DO (mg/L)	pH	Temp (°C)	Salin (ppt)	Cond (ms)	DO (mg/L)	pH
S	NC	12.64(0.62)	31.30(0.10)	48.14(0.11)	9.40(1.74)	7.97(0.19)	16.45(0.70)	31.67(0.12)	48.43(0.16)	11.27(1.02)	8.26(0.07)
S	HC	12.86(0.78)	31.38(0.06)	46.67(1.47)	9.98(1.02)	7.99(0.15)	15.67(0.91)	31.60(0.12)	48.49(0.17)	9.69(0.90)	8.30(0.06)
S	FC	12.57(0.80)	31.56(0.43)	48.01(0.11)	9.47(1.51)	7.80(0.17)	17.18(0.92)	31.50(0.14)	48.16(0.18)	11.78(1.18)	8.58(0.12)
Q	NC	9.29(0.41)	31.53(0.05)	48.73(0.09)	10.58(1.90)	8.06(0.10)	14.93(0.52)	31.48(0.37)	48.16(0.56)	14.01(0.87)	8.62(0.08)
Q	HC	10.09(0.90)	31.52(0.08)	48.41(0.14)	9.35(0.65)	7.97(0.18)	15.85(0.51)	31.23(0.55)	47.84(0.78)	11.03(0.65)	8.43(0.04)
Q	FC	10.00(0.65)	30.02(1.26)	46.41(1.92)	11.65(0.75)	8.08(0.14)	14.97(0.56)	31.28(0.35)	47.93(0.50)	10.15(0.69)	8.42(0.07)
GW	NC	14.91(1.23)	31.42(0.07)	48.13(0.15)	10.85(1.31)	8.40(0.2)	14.89(0.60)	31.71(0.16)	48.57(0.22)	7.71(0.57)	8.06(0.14)
GW	HC	14.13(1.11)	30.90(0.62)	47.41(0.85)	9.98(1.28)	8.23(0.32)	14.33(0.37)	31.43(0.36)	48.22(0.51)	9.23(1.30)	8.18(0.11)
GW	FC	15.49(1.29)	30.56(0.82)	46.99(1.09)	9.45(1.62)	8.16(0.38)	15.18(0.53)	31.33(0.50)	47.99(0.71)	10.21(1.14)	8.36(0.12)

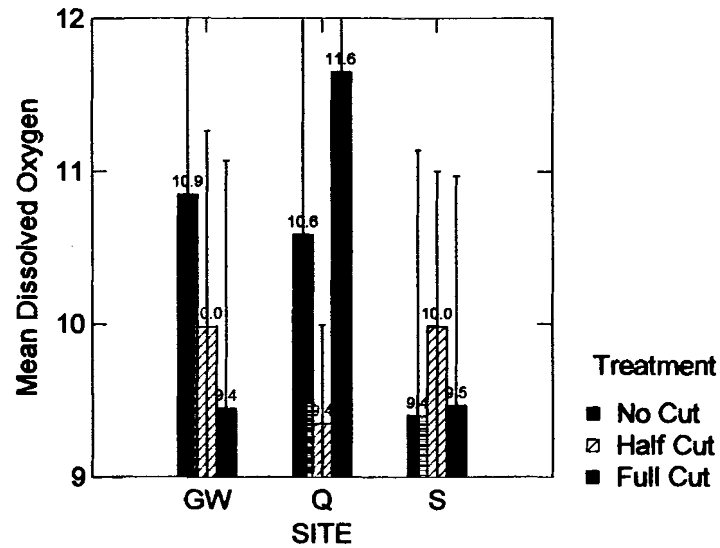


Before Treatment

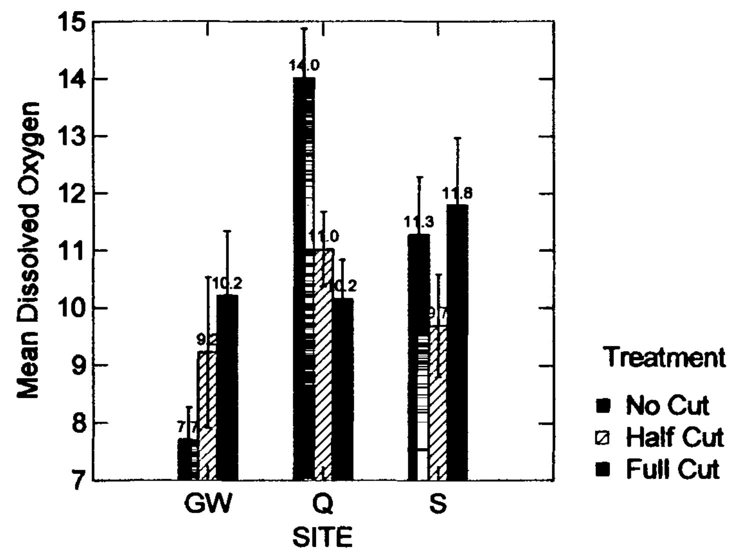


After Treatment

Figure 3: Mean temperature for each treatment at each site before and after assignment of treatment. GW= Great Wass, Q= Quoddy Head, S=Schoodic Point. Bars represent Standard Error.



Before Treatment



After Treatment

Figure 4: Mean dissolved oxygen for each treatment at each site, before and after assignment of treatment. GW= Great Wass, Q= Quoddy Head, S=Schoodic Point. Bars represent Standard Error.

Table 2: Mean number of fishes before and after assignment of treatment. Standard error is presented in parenthesis for each mean. S=Schoodic Point, Q=Quoddy Head, GW=Great Wass. R=Rockweed Fringe D=Dip-netted in tidepool.

Site	R/D	Trt	Before treatment Mean fish (SE)	After treatment Mean fish (SE)
S	R	No Cut	0.444(0.242)	0.333(0.256)
S	R	Half Cut	0.333(0.236)	0.333(0.142)
S	R	Full Cut	0.000(0.000)	0.000(0.000)
S	D	No Cut	3.222(1.681)	3.250(1.493)
S	D	Half Cut	1.889(1.285)	1.083(0.468)
S	D	Full Cut	0.222(0.147)	0.083(0.083)
Q	R	No Cut	0.111(0.111)	0.083(0.083)
Q	R	Half Cut	0.667(0.289)	0.250(0.179)
Q	R	Full Cut	0.111(0.111)	0.000(0.000)
Q	D	No Cut	2.778(1.164)	1.417(0.529)
Q	D	Half Cut	0.444(0.176)	2.417(0.701)
Q	D	Full Cut	0.333(0.167)	0.833(0.241)
GW	R	No Cut	0.333(0.167)	0.333(0.188)
GW	R	Half Cut	0.111(0.111)	0.000(0.000)
GW	R	Full Cut	0.444(0.338)	0.000(0.000)
GW	D	No Cut	3.222(1.256)	2.417(0.783)
GW	D	Half Cut	4.667(1.732)	7.250(2.722)
GW	D	Full Cut	0.444(0.338)	0.083(0.083)

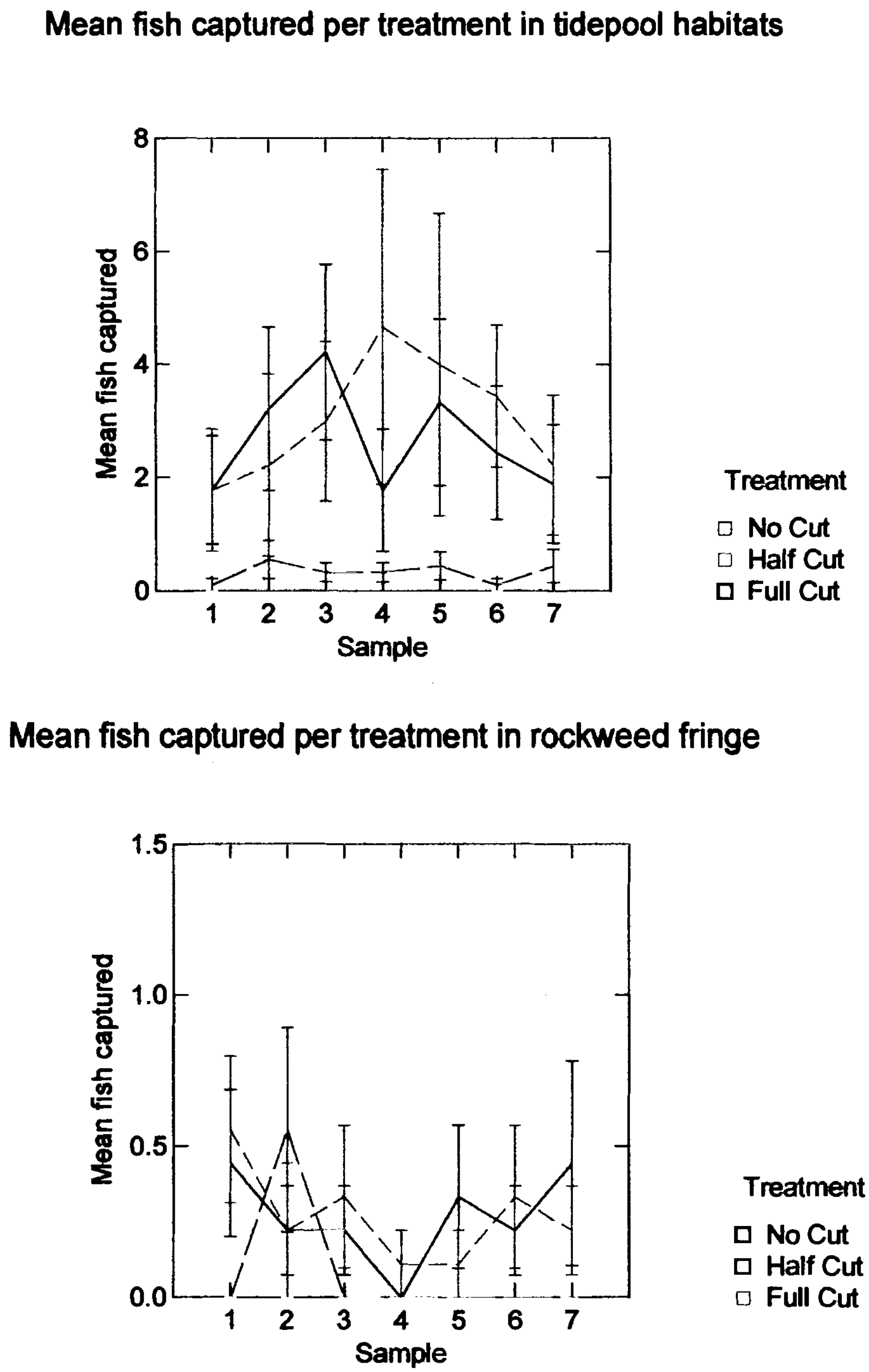


Figure 5: Mean fish captured per sample. Treatment occurred after sample 3. Bars represent standard error.

majority of the fishes captured, and the other species are all at least seasonal residents of tidepools (Table 3). Of the 420 total individuals, 38 individuals of 5 species (lumpfish, rock gunnel, Atlantic snailfish, shorthorn sculpin, and grubby) were captured in the rockweed fringe.

Mean numbers of invertebrates were highly variable (Table 4, Figure 6, 7). These totals represent a diverse array of food items, including Cirrapedia, Isopoda, Amphipoda, Mysidacea, Copepoda, Decapoda, Acarina, Polychaeta, terrestrial invertebrates, invertebrate larvae, and eggs. Because of the high variation in numbers, ranging from 6 to 13242 individuals per sample, these data were log transformed before conducting statistical analyses.

Apparent trends in the data for both invertebrates and fishes are not clear. The only obvious trend is the difference between the number of fish and invertebrates in the rockweed fringe vs. the remaining tidepool habitats (Figure 5, 6, 7). High variability and large standard errors for each mean make initial observational conclusions difficult to determine. Analysis of variance was used to help determine any other patterns that may be present within the data.

Factors Determining Fish and Invertebrate Presence: ANOVA

Data were analyzed with a split-plot analysis of variance (ANOVA), using the GLM option of SYSTAT 10. ANOVAs were used not only for the variables of total fish and total invertebrates, but also for individual species or groups that were represented in high numbers. For fishes, this included lumpfish, shorthorn sculpins, rock gunnel, and Atlantic seasnail.

Table 3: Fish species captured in the greatest abundance, with total number captured per habitat type. Notice the high abundance of lumpfish.

Species	Total captured	Number in Rockweed	Percent
Lumpfish *C. lumpus*	221	7	3%
Atlantic seasnail *L. atlanticus*	62	2	3%
Shorthorn sculpin *M. scorpius*	74	15	20%
Rock gunnel *P. gunnellus*	23	12	52%
Grubby *M. aenaeus*	16	2	13%
Atlantic herring *C. harengus*	10	0	0%
Three-spine stickleback *G. aculeatus*	5	0	0%
Sandlance *A. americanus*	4	0	0%
Pollock *P. virens*	3	0	0%
American eel *A. rostrata*	1	0	0%
Atlantic cod *G. morhua*	1	0	0%
TOTAL	**420**	**38**	

Table 4: Mean number of total food items (invertebrates and eggs) before and after assignment of treatment. Standard error is presented in parenthesis for each mean. S=Schoodic Point, Q=Quoddy Head, GW=Great Wass. R=Rockweed D=Dip-netted in tidepool.

Site	R/D	Trt	Before treatment Mean food items (SE)	After treatment Mean food items (SE)
S	R	No Cut	427.222(171.067)	253.083(61.683)
S	R	Half Cut	534.000(121.629)	421.000(83.455)
S	R	Full Cut	385.778(99.892)	277.750(109.339)
S	D	No Cut	1009.333(452.148)	947.333(290.825)
S	D	Half Cut	1622.778(494.079)	2529.500(1177.315)
S	D	Full Cut	2048.556(894.887)	5602.833(4084.957)
Q	R	No Cut	2722.000(1518.057)	226.500(61.743)
Q	R	Half Cut	350.778(116.203)	181.333(39.276)
Q	R	Full Cut	547.889(326.022)	61.333(11.065)
Q	D	No Cut	13242.000(8842.104)	2927.917(900.633)
Q	D	Half Cut	1790.778(1286.424)	907.333(507.354)
Q	D	Full Cut	1183.000(709.640)	765.500(314.067)
GW	R	No Cut	3787.333(1075.154)	1960.500(464.637)
GW	R	Half Cut	1211.667(240.476)	616.000(200.006)
GW	R	Full Cut	2739.889(1089.186)	4943.250(3458.376)
GW	D	No Cut	12739.556(5564.321)	7733.500(3132.164)
GW	D	Half Cut	2663.111(862.647)	1045.250(242.181)
GW	D	Full Cut	5303.444(1581.991)	6135.667(2205.303)

Rockweed Habitat

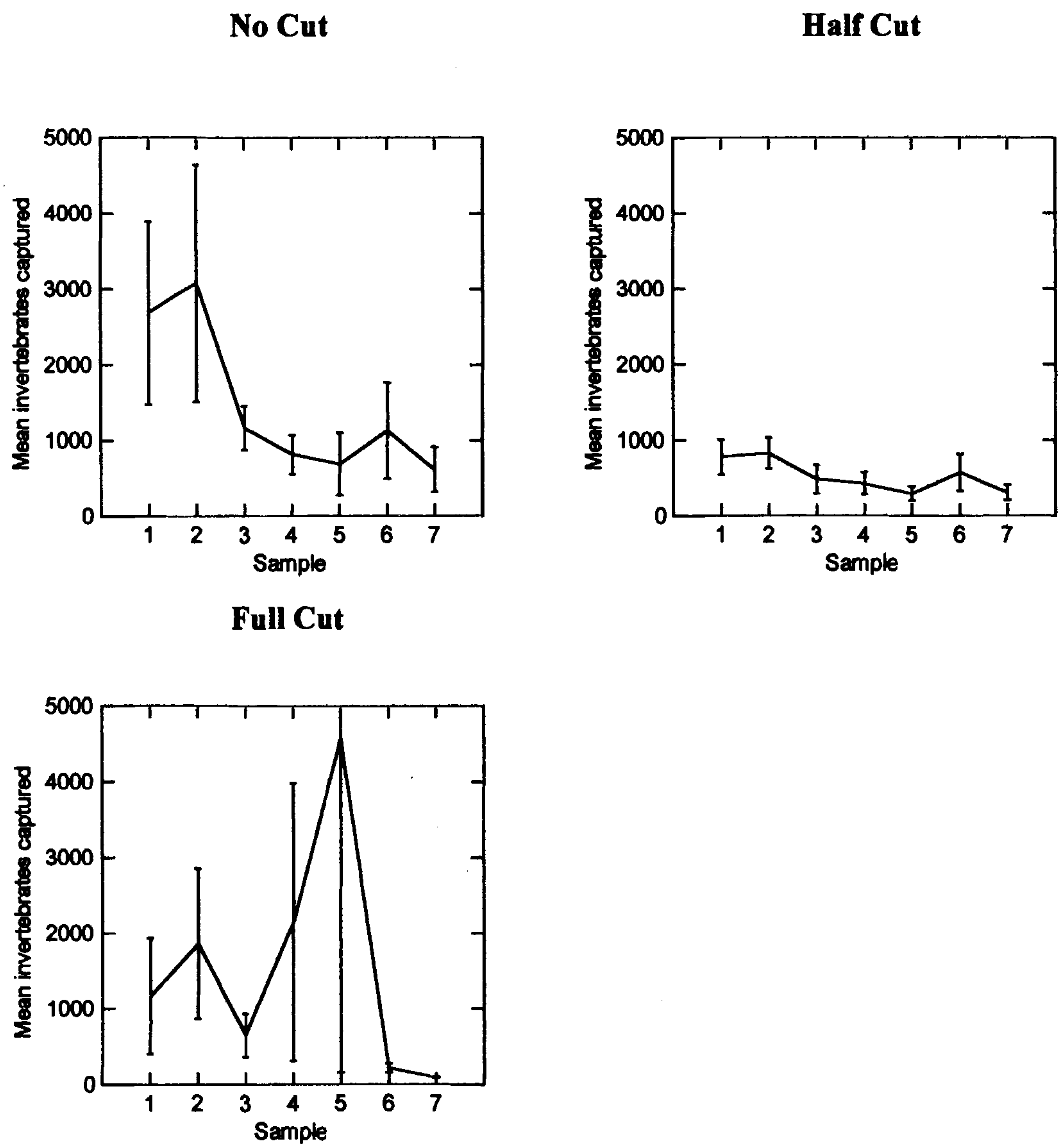


Figure 6: Mean number of invertebrates captured per sample in rockweed habitat. Treatment occurred after sample 3. Bars represent standard error

Remaining Tidepool Habitats

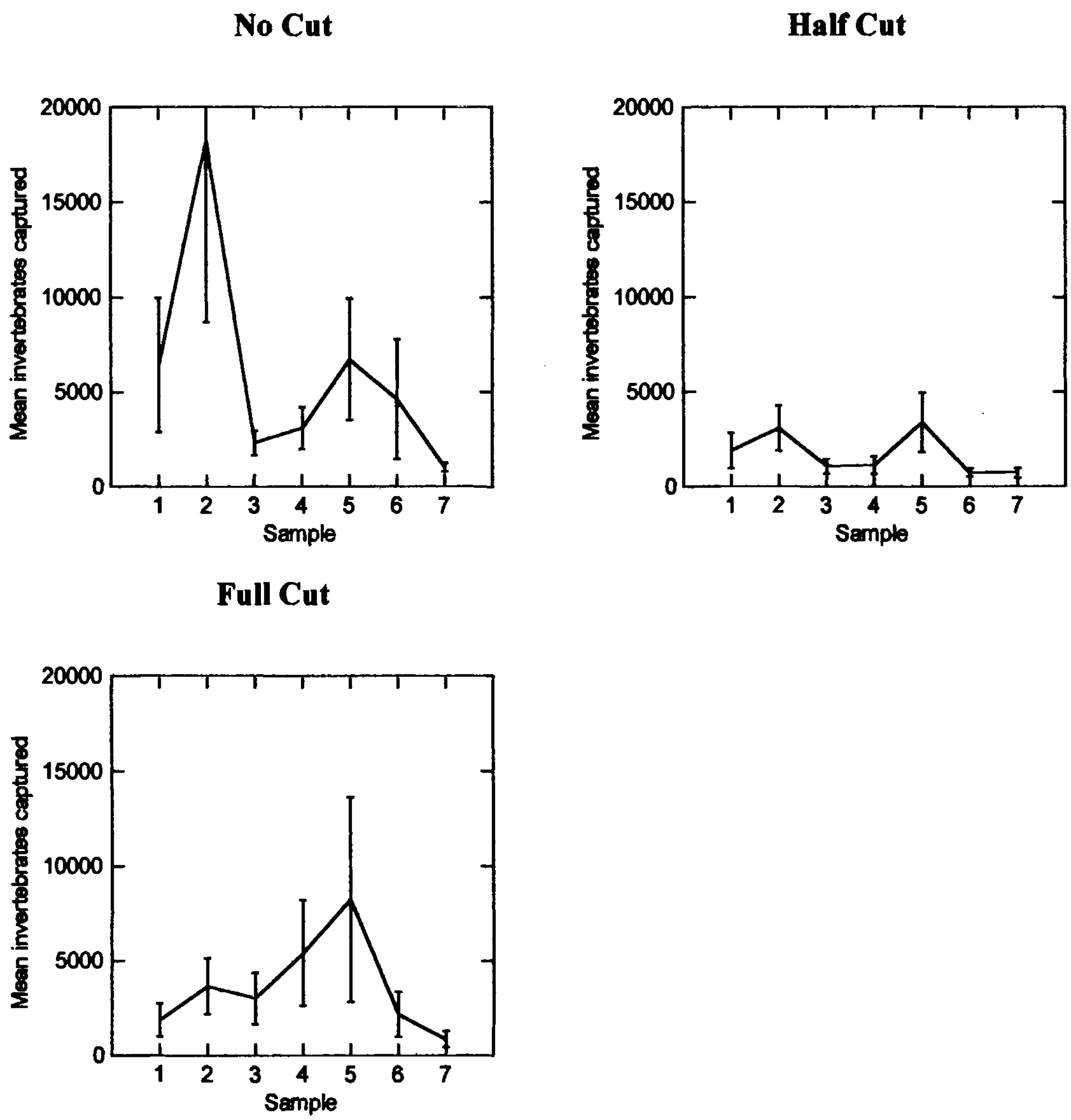


Figure 7: Mean number of invertebrates captured per sample in remaining tidepool habitats. Treatment occurred after sample 3. Bars represent standard error

For invertebrates, analyses were performed for Isopoda, Amphipoda, Copepoda, Acarina, *Cunio* spp. larvae, and eggs. Individual ANOVA tables are not included in this text, but are listed with significant F-tests indicated in Appendix B. Results for total fish and invertebrate ANOVAs are included (Table 5, 6)

For the dependent variable Total fish, the only significant test was that for RW/Dip, that is, the difference between rockweed fringe and tidepool habitat (Table 7). The result, with $\alpha = 0.05$, had a P-value of 0.001. Because of this, I reject the null hypothesis of no difference and conclude that there was a difference in number of fishes in the rockweed fringe vs. the tidepool habitat (Figure 8). Analysis of individual species yielded similar results, with the only exception being the rock gunnel, which also had a significant value for the interaction between the variables RW/Dip and Before/after ($\alpha = 0.05$, $P = 0.040$). In many cases, error terms for the variable Treatment were high, and this may cloud interpretation of results.

Similar results were found for total invertebrates (Table 8). The variable treatment again had a high error term, making it difficult to determine treatment effects. However, there were significant values for the variables Before/after ($\alpha = 0.05$, $P=0.003$), RW/Dip ($\alpha = 0.05$, $P=0.000$), and the interaction between these variables ($\alpha = 0.05$, $P=0.000$) (Table 8). So, in terms of invertebrates, I reject the null hypothesis of no difference for both the variables Before/after and RW/Dip, and conclude that the number of invertebrates captured was significantly different before and after treatment, and between rockweed fringe and tidepool habitat. Invertebrate numbers were lower before treatment than after, and lower in rockweed fringe vs. the remaining tidepool habitat.

Table 5: Results of the split-plot ANOVA for the dependent variable, total fish. S=Site, T=Treatment, B=Before and After, R=Rockweed or Tidepool, P= Pool.

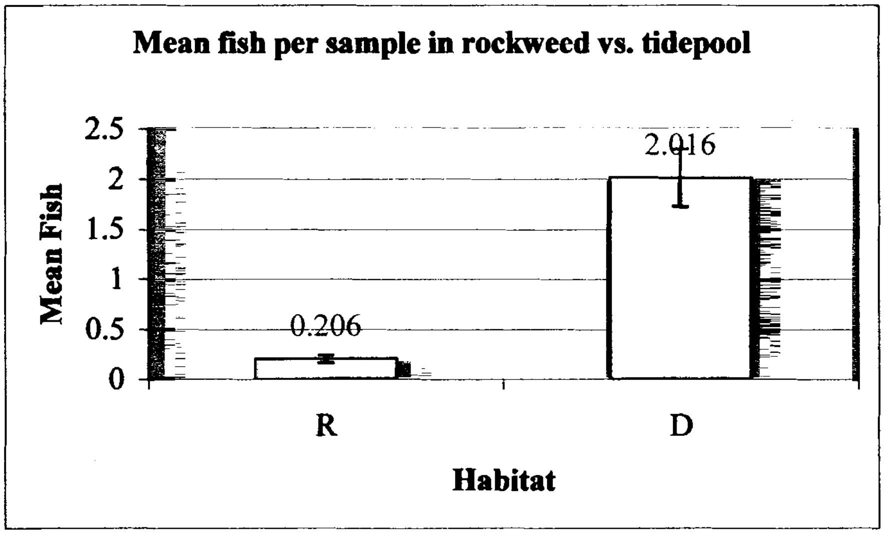
Source	Sum-of Squares	df	P-value
S	7.040	2	0.000
T	9.205	2	0.000
B	0.087	1	0.544
R	19.445	1	0.000
T*B	0.276	2	0.558
T*R	4.803	2	0.000
R*B	0.075	1	0.573
T*R*B	0.670	2	0.243
P(T)	39.487	16	0.000
B*P(T)	3.451	16	0.552
R*P(T)	20.932	16	0.000
R*B*P(T)	3.121	16	0.653
Error	70.666	300	

Table 6: Results of the split-plot ANOVA for the dependent variable, total invertebrates. S=Site, T=Treatment, B=Before and After, R=Rockweed or Tidepool, P= Pool.

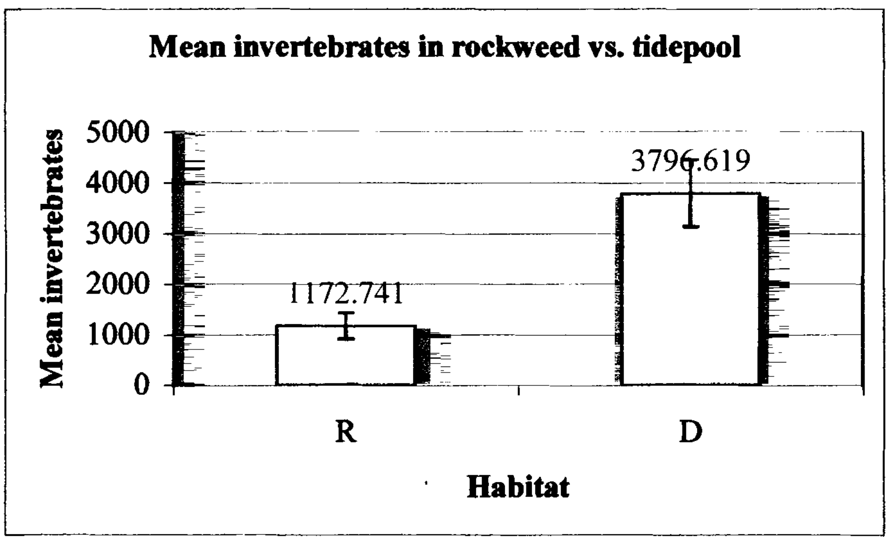
Source	Sum-of Squares	df	P-value
S	123.161	2	0.000
T	28.029	2	0.000
B	24.877	1	0.000
R	111.060	1	0.000
T*B	0.407	2	0.836
T*R	4.076	2	0.167
R*B	7.002	1	0.013
T*R*B	2.185	2	0.382
P(T)	153.656	16	0.000
B*P(T)	31.960	16	0.035
R*P(T)	13.141	16	0.767
R*B*P(T)	4.977	16	0.998
Error	339.569	300	

Table 7: Results of hypothesis tests (F-tests) for the dependent variable total fish.

Independent Variable	Source	SS	df	MS	F	P
Treatment	Hypothesis	9.205	2	4.603	1.865	0.187
	Error	39.487	16	2.468		
Before/after	Hypothesis	0.087	1	0.087	0.403	0.534
	Error	3.451	16	0.216		
Treatment x Before/after	Hypothesis	0.276	2	0.138	0.639	0.541
	Error	3.451	16	0.216		
Rockweed/Tidepool	Hypothesis	19.445	1	19.445	14.863	0.001
	Error	20.932	16	1.308		
Rockweed/Tidepool x Treatment	Hypothesis	4.803	2	2.402	1.836	0.192
	Error	20.932	16	1.308		
Rockweed/Tidepool x Before/after	Hypothesis	0.075	1	0.075	0.385	0.544
	Error	3.121	16	0.195		
Rockweed/Tidepool x Before/after x Treatment	Hypothesis	0.670	2	0.335	1.718	0.211
	Error	3.121	16	0.195		



Fishes



Invertebrates

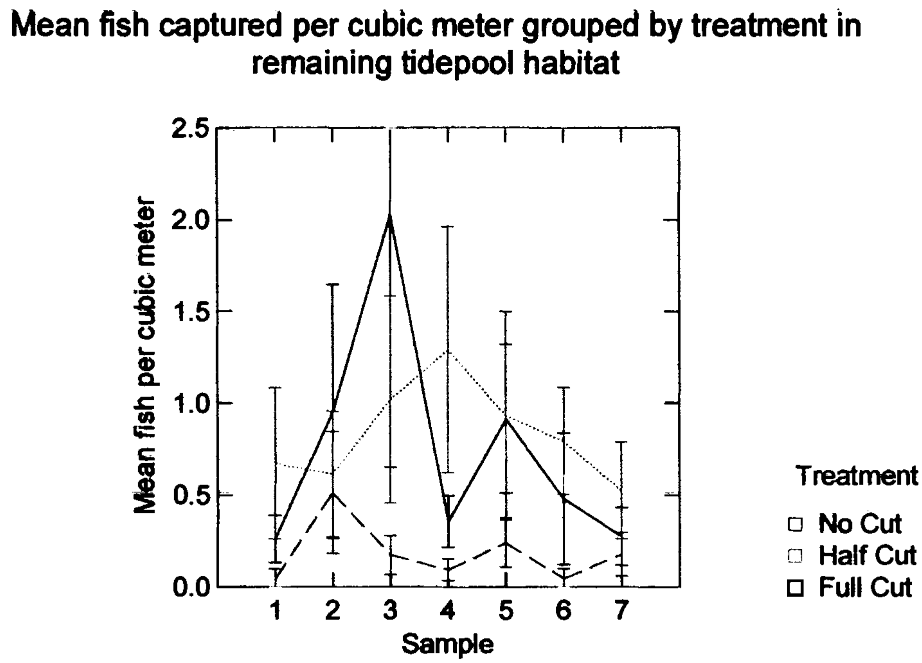
Figure 8: Mean fishes and invertebrates in rockweed habitat vs. other tidepool habitats. Bars represent standard error. R=Rockweed, D=Dip-netted in tidepool.

Table 8: Results of hypothesis tests (F-test) for the dependent variable total invertebrates.

Independent Variable	Source	SS	df	MS	F	P
Treatment	Hypothesis	28.029	2	14.014	1.459	0.262
	Error	153.656	16	9.604		
Before/after	Hypothesis	24.877	1	24.877	12.454	0.003
	Error	31.960	16	1.998		
Treatment x Before/after	Hypothesis	0.407	2	0.203	0.102	0.904
	Error	31.960	16	1.998		
Rockweed/Tidepool	Hypothesis	111.060	1	111.060	135.227	0.000
	Error	13.141	16	0.821		
Rockweed/Tidepool x Treatment	Hypothesis	4.076	2	2.038	2.482	0.115
	Error	13.141	16	0.821		
Rockweed/Tidepool x Before/after	Hypothesis	7.002	1	7.002	22.511	0.000
	Error	4.977	16	0.311		
Rockweed/Tidepool x Before/after x Treatment	Hypothesis	2.185	2	1.093	3.513	0.054
	Error	4.977	16	0.311		

Analysis of individual invertebrate groups had similar results, with one distinct exception being the Isopoda. No independent variables yielded significant results, which is interesting because all other tests had a significant value for RW/Dip. However, in the Isopoda, it appears there are equal numbers in the rockweed fringe as compared to the other tidepool habitat.

When the fish and invertebrate counts are standardized for the volume of the tidepool sampled, the results follow similar patterns as the raw data (Figures 9, 10, 11). These patterns are also reflected in the split-plot ANOVA, with some exceptions. These include total invertebrates, which after being standardized per volume sampled, displayed no significant difference between the rockweed fringe habitat and the remaining tidepool habitats. Similarly three species of fishes, Atlantic snailfish, rock gunnels, and shorthorn sculpins showed no significant differences between rockweed and other tidepool habitat after standardization. This means that for these species, the other tidepool habitats and the rockweed fringe are equally utilized. Finally, the numbers of isopods, when standardized for volume, were significantly different between rockweed fringe habitat and other tidepool habitats: 68.65 individual per m^3 in the rockweed fringe, and 22.42 individual per m^3 in the other tidepool habitats. This implies that isopods are more concentrated in the rockweed fringe than in all of the remaining tidepool habitats.



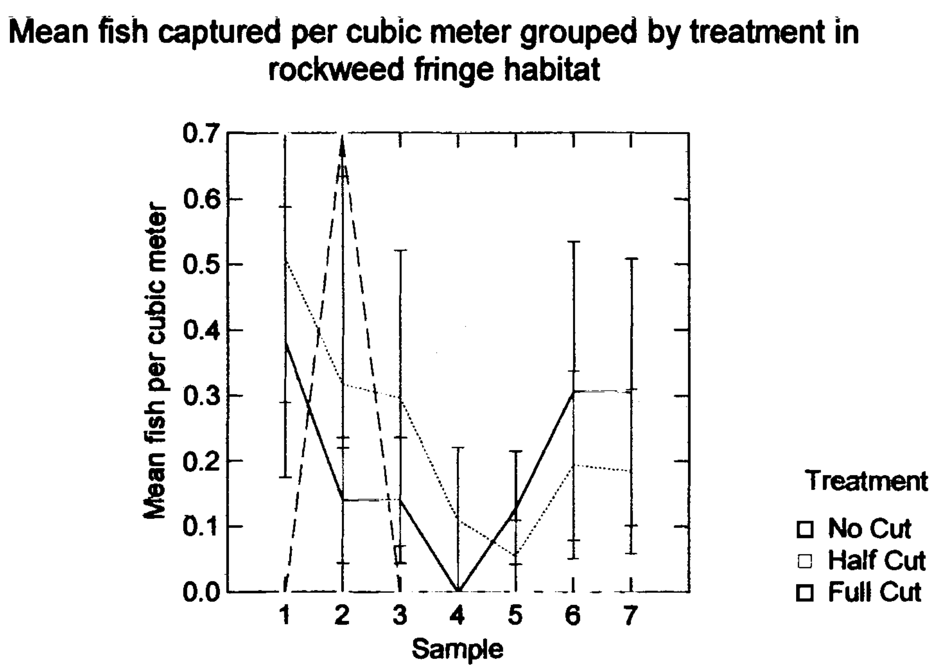


Figure 9: Mean fish per cubic meter captured per sample. Treatment occurred after sample 3. Bars represent standard error.

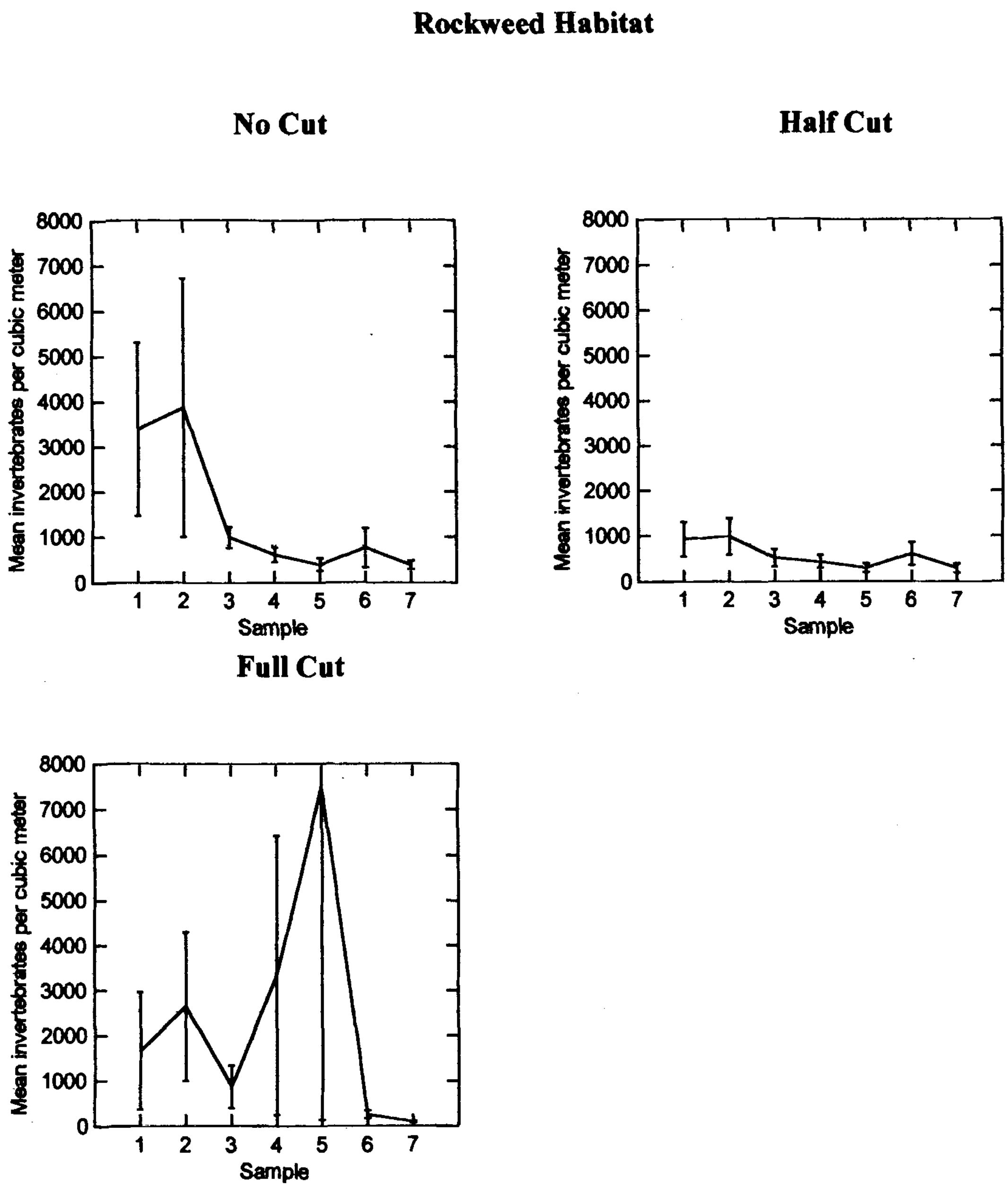


Figure 10: Mean number of invertebrates per cubic meter captured per sample in rockweed fringe habitat. Treatment occurred after sample 3. Bars represent standard error

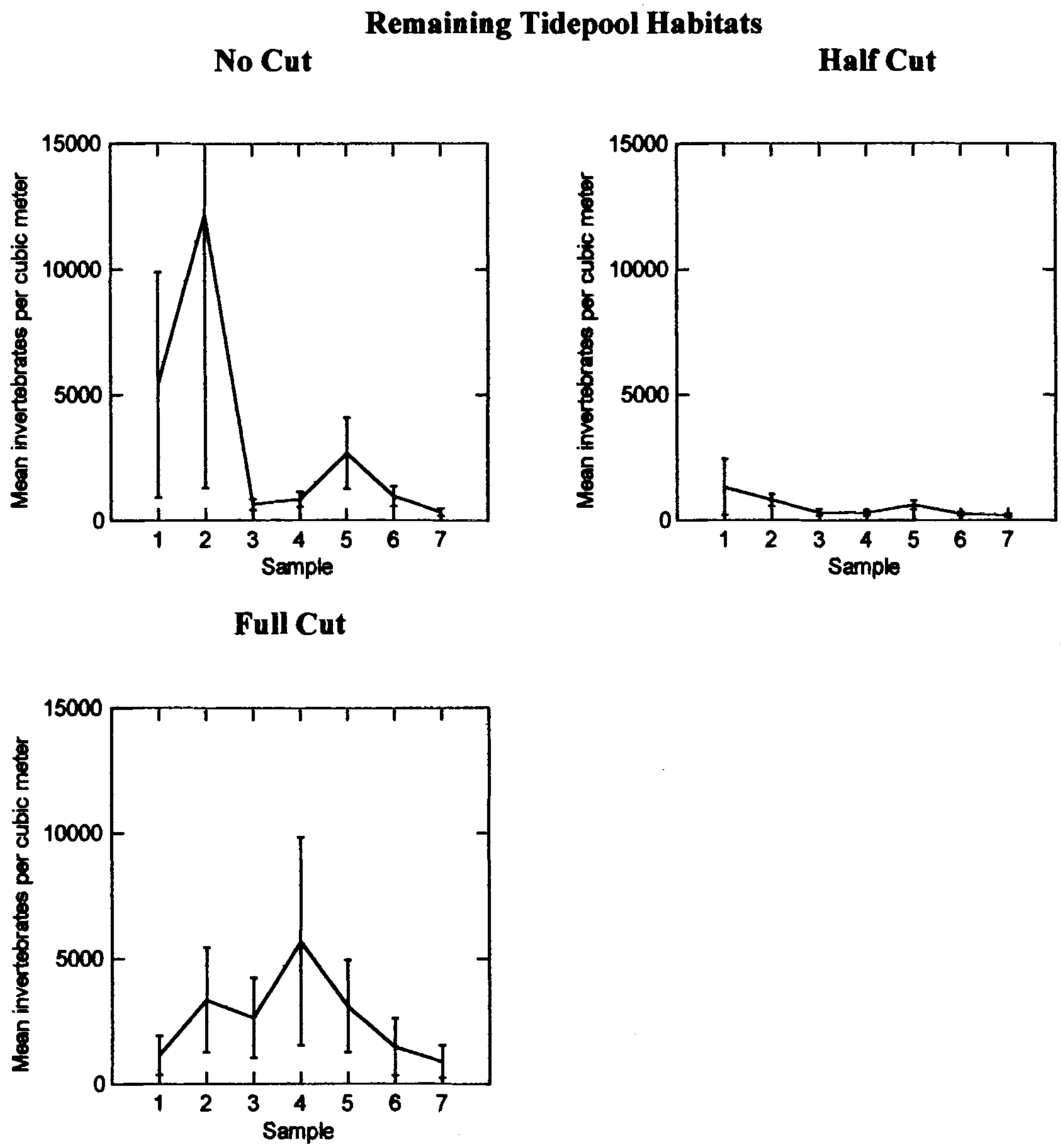


Figure 11: Mean number of invertebrates captured per cubic meter per sample in remaining tidepool habitats. Treatment occurred after sample 3. Bars represent standard error

Developing a model for fish presence

The significant amount of error in all ANOVAs reinforces the inherent variability of tidepools, in terms of species presence. With the physical and biological data collected during the field season, I have attempted to devise a logistic regression model that could account for fish presence in pools, and possibly identify the reasons why some pools contained fish, while others, including many pools at Schoodic Point, never contained fish.

The best-fitting model to determine fish presence in tidepool habitat was one that included the variable Dominant Substrate only (Table 9). This model resulted in a Pearson's chi square value of 18.021, with 21 degrees of freedom, and a P-value of 0.648. Because the P value is greater than $\alpha = 0.05$, I can accept the null hypothesis that the data are not significantly different from the model, and conclude the model fits. When the variable Treatment is added to the model, it did not improve the fit of the model. However, it did fit the data, resulting in a lower P-value of 0.306 (Table 9). Probability of fish presence (Figures 12, 13) was calculated from the parameter estimates given by the model, using the equation:

$$\text{Probability} = \exp(\alpha + \beta x) / 1 + \exp(\alpha + \beta x) \qquad \text{(Agresti 1996)}$$

As for determination of fish presence in rockweed fringe, the best fitting model included the variable Surface area only (Table 9). The model resulted in a Pearson's chi square value of 26.592, with 25 degrees of freedom, giving a value of $P = 0.377$. This value is greater than $\alpha = 0.05$, so again I accept the null hypothesis, and conclude that the model fits the data well. Adding the independent variable Treatment to the model

Table 9: Description of model terms for best fitting logistic regression models. Parameter estimates and goodness of fit values are presented for each model.

Habitat	Independent Variables	Parameters	Parameter Estimates	Pearsons chi squared (Goodness of fit)
Tidepool	Dominant Substrate	α	0.405	
		β (Brown)	-0.405	
		β (Green)	-1.099	
		β (Mixed)	1.792	
		β (Rock)	0.405	18.021 (P = 0.648)
	Dominant Substrate and Treatment	α	-0.087	
		β (Brown)	-0.460	
		β (Green)	-1.147	
		β (Mixed)	1.581	
		β (Rock)	-0.087	
		β (No cut)	1.137	
		β (Half cut)	0.711	
		β (Full cut)	-0.087	23.738 (P = 0.306)
Rockweed	Surface Area	α	-1.772	
		β	0.048	26.592 (P = 0.377)
	Surface Area and Treatment	α	-17.813	
		β (No cut)	-1.238	
		β (Half cut)	-1.383	
		β (Full cut)	-17.813	15.953 (P = 0.857)

improves the fit further, resulting in a p-value of 0.857 (Table 9). Although probability estimates were not conducted due to the continuous nature of the variable Surface area, one can see from the positive value of the parameter estimate that as surface area increases, so does the probability of a fish being present. Also, in terms of the variable Treatment, as the parameter estimate decreases, so does the resulting probability of fish presence. So, from these estimates, I conclude that the no cut treatment is most likely to have fish present, and full cut treatment is the least likely. This corresponds with the results for tidepool habitat above. However, if you consider the actual data, the trend hinted to in the models appears to be less of a treatment effect and more likely an inherent difference between treatments (Figure 14). For example, the number of pools with fish present in treatment 3 for tidepool habitat is always lowest, even before treatment is performed. Inherent variability between treatments must be controlled before it is clear whether a treatment effect exists or not.

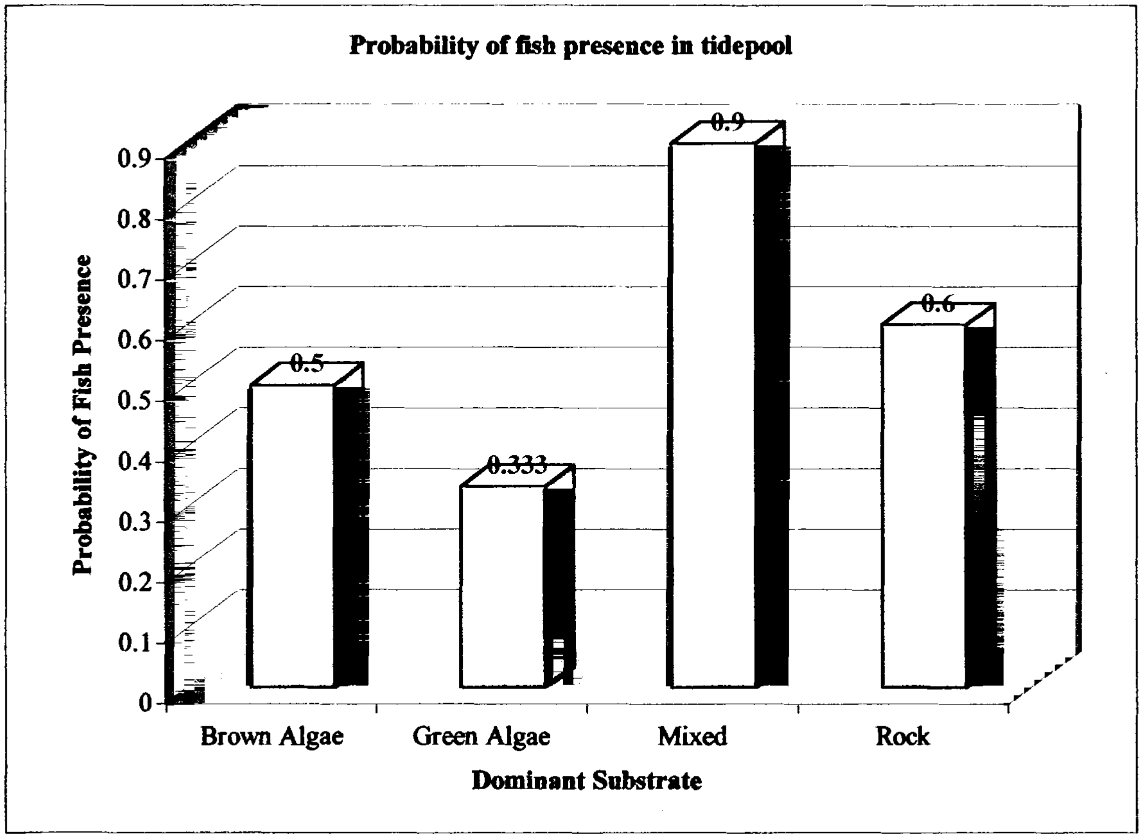


Figure 12: Probability of fish presence in other tidepool habitats for each type of dominant substrate. Probabilities were calculated from parameter estimates of the logistic regression model with the independent variable Dominant Substrate only.

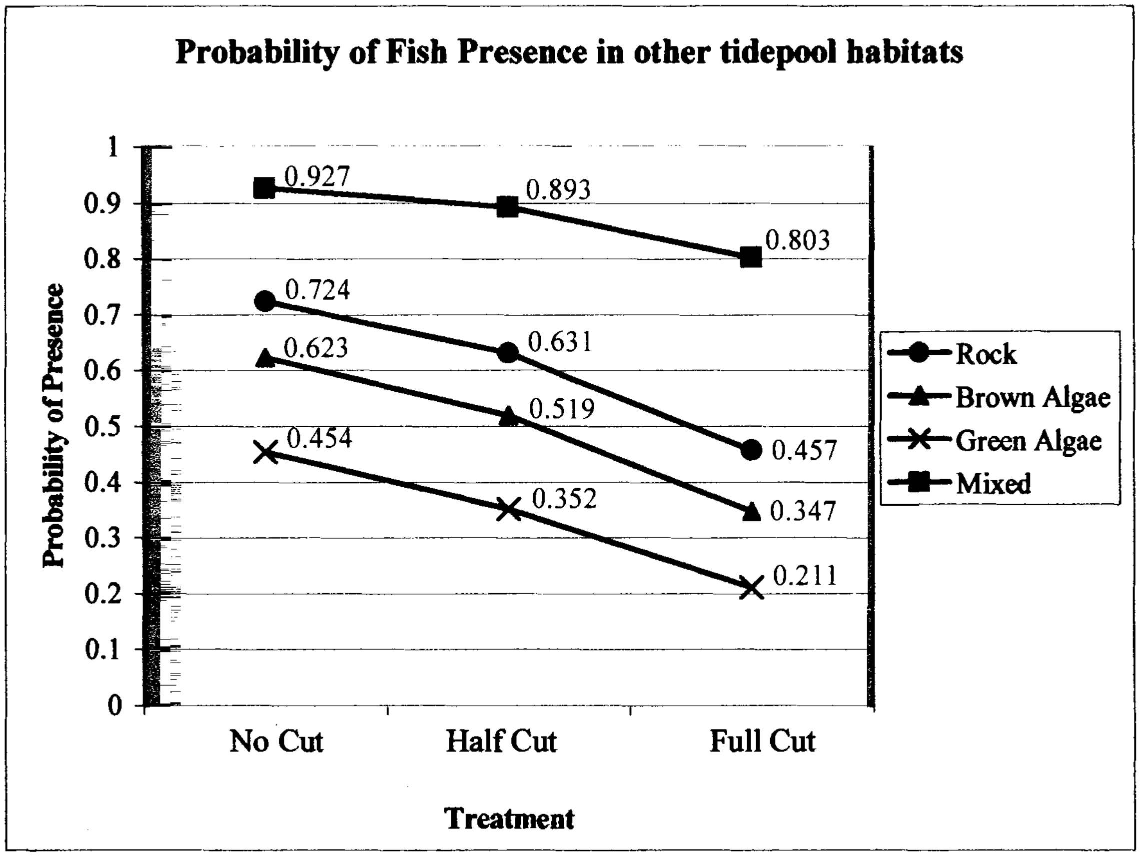
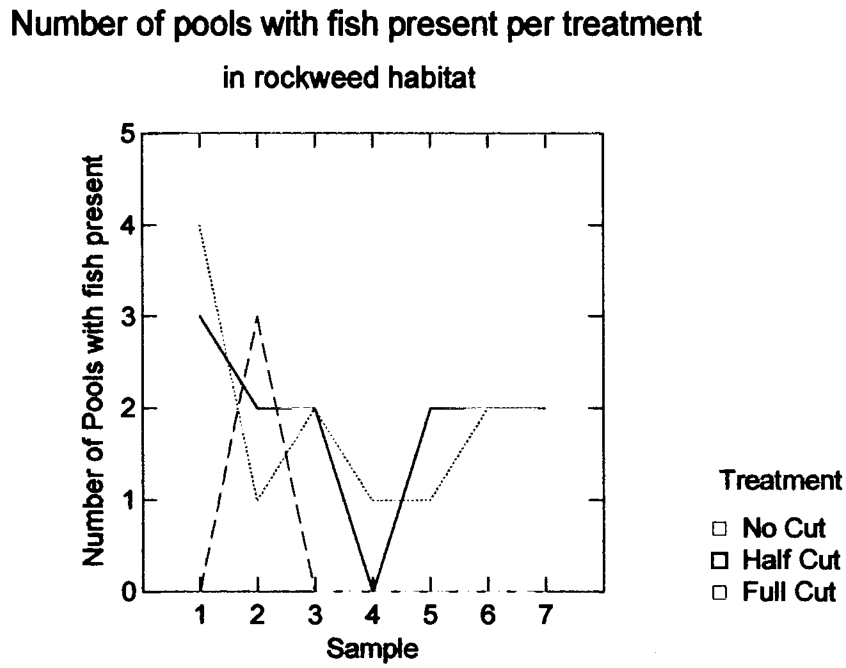


Figure 13: The probability of fish presence for each dominant substrate type per treatment. Probabilities are based on parameter estimates resulting from a logistic regression model with the independent variables Dominant substrate and Treatment.



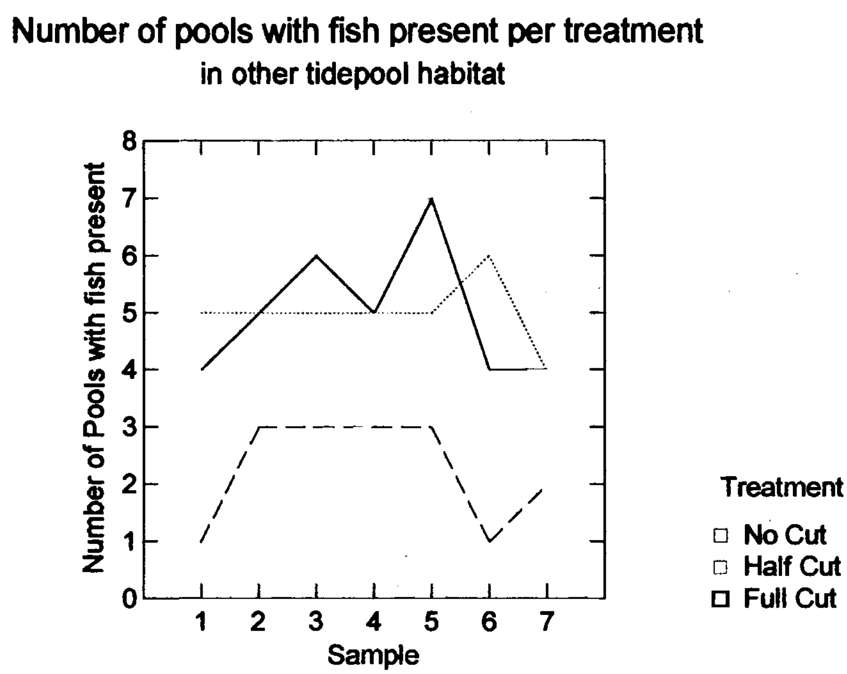


Figure 14: Number of pools per sample that contain fish in rockweed and other tidepool habitats. Treatment occurred after sample 3.

DISCUSSION

Fish and Invertebrate Presence

The first objective of this study was to document the presence of fish in rockweed fringe. Of the 11 species and 420 individual fishes captured in tidepools, 5 species and 38 individuals were captured in the rockweed fringe: lumpfish, shorthorn sculpin, grubby, rock gunnel and Atlantic seasnail. This means some residents of tidepool habitat are utilizing the rockweed fringe. Many of these individuals were juveniles of subtidal adult species, suggesting that young fish may take refuge in tidepools before venturing into the open ocean. An interesting pattern was the high percentage of rock gunnels and shorthorn sculpins that were captured in the rockweed fringe. 52 percent of the rock gunnels, and 20 percent of the shorthorn sculpins were captured in this habitat. So although the overall numbers of fishes captured in the rockweed fringe are low, it is important to consider that this habitat might be important to individual species represented in a high percentage within the habitat.

The second objective was to determine the effect of an experimental removal of rockweed fringe. However, the results of the experimental component are somewhat unclear. The sampling method used to obtain fishes was sound (Yoshiyama 1986 et al., J. R. Moring, University of Maine, Orono, ME, *personal communication*), and the experiment was replicated. The lack of clarity is most likely due to the high variability of tidepools, which caused large biological and environmental differences within treatments. These differences within treatments made it difficult to detect true effects between treatments. Seasonality could also have played a role in such a short-term experimental season. Yet, some clear patterns did emerge from the data. Throughout the entire

sampling period, there were larger numbers of fishes in the tidepool habitat than in the rockweed fringe habitat. When samples were standardized for the volume sampled, to compensate for the fact that rockweed fringe only makes up a small portion of the tidepool, similar results were found. Total fishes remained significantly lower in the rockweed fringe. This is not surprising, since studies of tidepool fishes on the West Coast, and the data from this study (Figure 15) do not support that the number of fish present are directly related to the volume of the tidepool. Rather, complexity of substrate and presence of macroalgae are more predictive of fish presence (Nakamura 1976, Thomson and Lehner 1976,Yoshiyama et al. 1986, Pfister 1989, Pfister 1995). Differences between tidepool and fringe habitat could have been due to the higher number of diverse microhabitats in the entire pool as opposed to the fringe, or perhaps to high numbers of lumpfish, which appear to associate with strongly with *Laminaria* spp., a species common in many of the tidepools sampled (Moring 1989). This difference again shows the strong variability of tidepools in the field, and to control for this in future experiments, I suggest conducting an initial sampling to determine species presence, then perform experimental removal only on tidepools that initially contained the same species.

While the ANOVA suggests accepting the null hypothesis and determining that there was not a clear difference between experimental treatments, this would be misleading, because of high variability within treatments. Black and Miller (1991) were quick to conclude that removal of rockweed has no effect on fishes, when experimental error and lack of replication could have led to the lack of significance (Rangeley 1994).

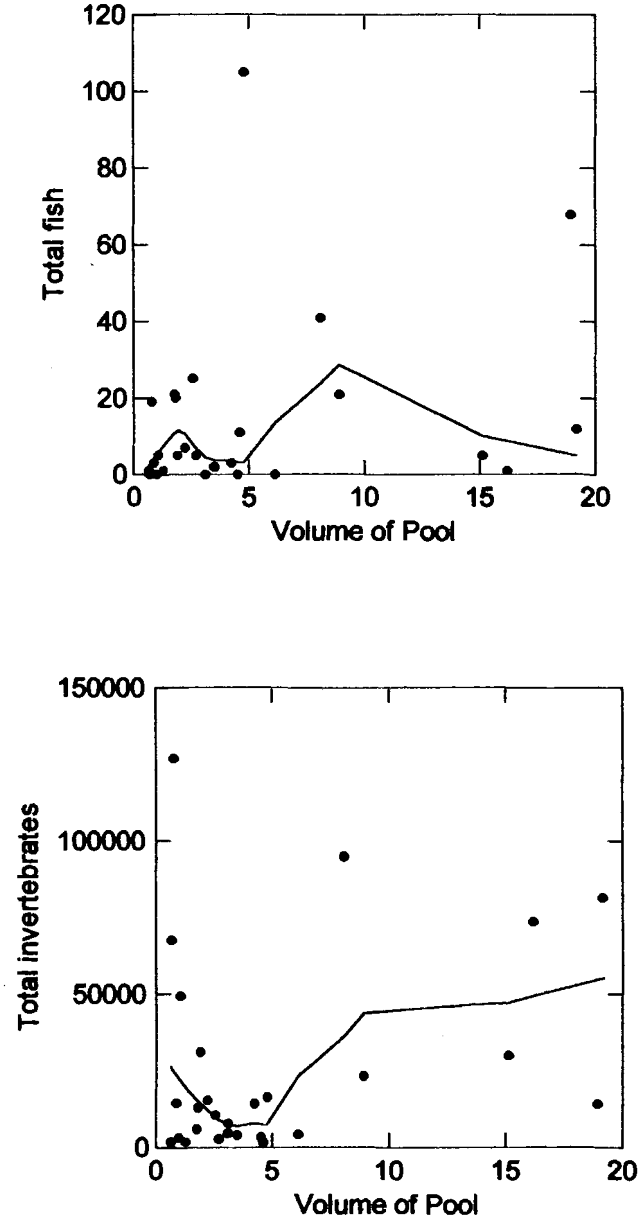


Figure 15: Total fish and invertebrates captured by volume (m^3) of the pool in which they were captured. Notice the lack of trend relating both number of fish and invertebrates to volume sampled.

At this point, I can safely conclude that, although the results of the experimental objectives of this study were unclear, the observational objective shows that tidepool fishes do utilize rockweed fringe as habitat.

An interesting trend did develop from the results of the logistic regression model for the dependent variable fish presence. Although the ANOVA was not able to distinguish treatment effects, the negative effect of treatment was displayed in the model parameter estimates. For both rockweed and tidepool habitats, the probability of fish presence decreased as rockweed fringe was removed (Figure 13), independent of which dominant substrate was present. This suggests that if the variability within treatments was controlled for, an ANOVA may be able to distinguish treatment effects.

Similar problems with the variability of intertidal habitat have been experienced during past research. Fegley (2001) was able to detect a decrease in the number of large invertebrates existing in rockweed habitat in harvested areas vs. unharvested areas, yet concluded that treatment effects may be greater if they had not been clouded by variability. Although her study did not address smaller invertebrate species, such as those consumed by tidepool fishes, she did detect a significant decrease in macroinvertebrates in conjunction with algal removal (Fegley 2001).

Yet, despite this potential for reduction in invertebrate numbers, the treatment effects on invertebrate abundance in my study are unclear. Lack of clarity could be due to random events, such as hatching, invertebrate aggregations, or sampling error. It is clear that there were significant amounts of groups that are consumed by tidepool fishes, including the Isopoda, Amphipoda, Copepoda, Acarina, as well as larvae of terrestrial invertebrates (*Cunio* spp), and eggs present in the rockweed fringe. The most important

conclusion that can be made from the invertebrate data is that prey items of tidepool fishes do exist in the rockweed fringe, and may be important to foraging tidepool fishes.

What Determines Fish and Invertebrate Presence: A Model

The results for tidepool habitat showed that a model with the variable Dominate substrate was the most effective at predicting fish presence. For rockweed fringe, a model with the variable Surface area had the best fit. For both models, when the variable Treatment was added, the model continued to fit the data, and the fit improved for the rockweed fringe model. This indicates it is possible that the treatment was a significant factor in determining if fish would be present in rockweed fringe and in the tidepool. Similar models have been developed in Europe, and have associated two members of the Blenniidae family with surface area, depth, and percent algal cover (Nieder 1993). Random chance also could play a role in the actual number of fishes present, which was not considered in my non-weighted model, due to a hatching of lumpfish eggs near by, or random floating of larval fishes into the area (Goulet et al. 1986, Lazzari 2000). However, it is interesting, as was noted earlier, that as rockweed is removed, the probability of having fish present in a pool does tend to decrease. Whether this trend was a result of true treatment effects or simply inherent variation between samples is not clear, and further experimentation that attempts to control further for variation may be able to make that distinction.

Characteristics of a Rockweed Habitat: Why Use It?

The use of rockweed as habitat for fishes has not been addressed extensively in the literature. The habitat is vast, stretching across most of the rocky intertidal shore

(Keser et al. 1981), and yet, research has all but ignored this resource as a useful area for fishes to forage and hide. Rockweed can be a valuable resource to fishes, not only as a place to find food, but also as a place to hide from avian predators. The structure of rockweed itself also can supply support for fish that lack air bladders and the ability to remain buoyant in tidepools. And finally, for at least one species, the threespine stickleback, rockweed may provide adequate cover for successful nesting in the intertidal zone (Gullo, *personal observation*).

One of the objectives of this research was to assess the number of prey items located in rockweed fringe as opposed to the tidepool habitat. The results did not show a clear trend. However, much of this can be accounted to experimental error and inter-pool variability. When sampling the tidepool areas, I not only dip-netted the open water column, but also the associated algae, such as *Laminaria* spp., *Ulva lactuca*, etc. Many species of invertebrates could have been associated with these algal species (Dethier 1980, Coull and Wells 1983, Hull 1987, Kneib 1987, Moring 1989, Sogard and Able 1991). Decreasing the number of pools studied, to take a more detailed look at where species occur within individual tidepools, and examining more microhabitats, other than just "rockweed", would be one approach that might improve the interpretation of invertebrate counts.

Past experiments have clearly shown associations of invertebrates with fresh water species of submerged aquatic vegetation (SAV) as well as estuarine plant species (Rozas and Odum 1988, Hosn and Downing 1994, Rossier et al. 1996, Richardson et al. 1998, Heckert et. al 1999, VanderKooy et al. 2000, Castellanos and Rozas 2001, Farrell 2001). These studies cite the role of vegetation as a refuge for the invertebrates from

other potential predators. This SAV provides sufficient refuge because it offers not only substrate, but also structural complexity. Manatunge et al. (2000) showed that there is often a tradeoff for fishes that are foraging in aquatic vegetation. While there is an increased concentration of food, there also is a hindrance to the ability of fishes to swim, due to the structural complexity of the habitat. So, although the fish may be capturing larger food items, the trade off is not being able to catch high numbers of them (Manatunge et al. 2000).

A. nodosom has been cited as an algal species with which some invertebrate species will associate. While some studies focus on larger invertebrates (Wilbur and Steneck 1999, Fegley 2001), others focus on smaller invertebrates, which could be a source of food for the smaller individuals captured in tidepools (Davenport and Rees 1993, Ingolfsson 1998). In a stomach analysis of juvenile lumpfish captured in tidepools at Schoodic Point, Maine, Moring (1989) showed that lumpfish commonly consume members of the Amphipoda and Copepoda. These same species were found in high numbers in the rockweed sampled in this experiment. High numbers of these invertebrates also were recorded for floating rockweed off the coast of Iceland (Ingolfsson 1998), and Davenport and Rees (1993) concluded that juvenile lumpfish located on the algae were "opportunistic weedpatch specialists," eating everything available.

Impediment of fish movement, mentioned earlier as a disadvantage to fish foraging in SAV, may not be a problem for the fish found associated with rockweed fringe in my study. The lumpfish is a relatively slow-moving fish (Moring 1989), and could benefit from having a surface on which to attach, and then slowly move along to

capture prey. Shorthorn sculpin are known to be sit-and-wait predators (Hanson and Lanteigne 2000), and rockweed could provide structural support for this species to wait for prey to pass by. And finally, the rock gunnel, being anguilliform-shaped, has the capability of "slithering" throughout the rockweed-- moving quite effectively (Gullo, *personal observation*). So, perhaps this trade off between locating prey and being able to capture the prey ends up being a positive one, resulting in a net gain for the fish.

Another reason a fish may use rockweed habitat is as a refuge from predators, whether fish, avian, or mammalian. It is well documented that fishes will use SAV as a refuge from predators when the fishes are in low number and cannot aggregate as a defense (Rangeley and Kramer 1998, Krause et al. 2000a, 2000b, Armstrong and Griffiths 2001). In terms of *A. nodosum,* Rangeley and Kramer (1998), found that juvenile pollock will use rockweed at high tide as a refuge from predation by the cormorant, *Phalacrocorax auritus*. As for the species captured in this study, their camouflage abilities are a testament to how well they can hide within the rockweed. This is best demonstrated by the lumpfish, which have the ability to change their coloration in response to the background. Davenport and Bradshaw (1995) noted that the best color match is between that of the lumpfish with *A. nodosum*. Moring (1994) noted that dark individuals would associate with eelgrass, *Zostera marina*, and brown individuals with *Laminaria saccharina* and *A. nodosum*. This ability to change color, along with their ventral suction disk and their shape, which closely mimics that of a rockweed receptacle, all make hiding in the rockweed easy for lumpfish. Atlantic snailfish also have a similar style of attachment and camouflage, although it is not as well documented. Rock gunnels, while typically associated with habitat underneath rocks, have a specific banding

pattern that would be an ideal camouflage amongst rockweed fronds. And finally, shorthorn sculpin, while not specifically hiding in the rockweed (since they are better camouflaged on the bottom of pools) are most likely utilizing the habitat to hunt for all the other fish that are hiding, as they are voracious predators of smaller fish (Gullo, *personal observation*).

There are two other considerations to make when assessing why fishes would use rockweed: support and reproduction. The first, though not well documented, is something to be considered, especially with species that do not maintain neutral buoyancy in the water column with an air bladder, such as the sculpins and gunnels. High percentages of these species were found associated with the rockweed fringe. A possible reason for this association may be to reduce expenditure of swimming energy. Rockweed fronds contain air bladders that keep the algae mats afloat, yet partially submerged, in tidepools. Both shorthorn sculpins and rock gunnels could be using the rockweed simply as structural support, for either foraging or perhaps aerial respiration, which has been recorded in similar species (Davenport and Woolmington 1981, Yoshiyama and Cech 1994, Martin 1995, Yoshiyama et al. 1995). Further study is needed before conclusions are made based on this assumption.

And finally, at least one species, the threespine stickleback, was observed reproducing in association with rockweed. Although the number of individuals captured were low (four), on two occasions, I captured a female laying eggs under the rockweed, and on one occasion, I actually netted a female and male pair-- the male in mating coloration. Threespine sticklebacks have been known to breed in the intertidal zone, and research has documented the use of macrophytes as nest cover (Candolin and Voigt 1998,

Kraak et al. 2000). In field experiments, females were found to prefer males with macrophyte-covered nests, and larger amounts of eggs per nest were found in these nests (Candolin and Voigt 1998, Kraak et al. 2000). Experimentation with another species of intertidal fish, the sharpnose sculpin *Clinocottus acuticeps*, has shown that eggs laid below a related species of rockweed (*Fucus distichus*) survived at a higher rate than did those laid in the open (Marliave 1981). Although not investigated fully with my experiment, the use of rockweed habitat during fish reproduction should be examined, as this may be an important role of this alga along the coast of Maine.

Conservation Implications: The Rockweed Harvest

While this experiment was not designed to replicate the rockweed harvest, assessing the value of rockweed to fishes in nature does have implications for the commercial harvest along the coast of Maine. The rockweed harvest does not result in a complete removal of rockweed from the shore however it does decrease the length of the fronds. Rockweed fringe in tidepools is made up of long fronds of intertidal rockweed that drape into the pool, forming the fringe. If the fronds are shortened, the algae will no longer reach the tidepool edge. Therefore, decreasing the length of the frond could effectively remove the rockweed fringe completely.

Although we were unable to demonstrate experimentally that removal of the fringe has an influence on species presence, limitations of the study rather than empirical data govern these results. At least five species of fishes have been found associated with the rockweed fringe of tidepools, and because experimental error clouds the implications of treatments, I believe it would be inappropriate to state that removal of this fringe

habitat has no effect on the presence of fishes. It is more responsible, due to the often low power of fisheries experiments (Toft and Shea 1983, Peterman 1990), that I conclude, although this particular experiment did not show effects of removal, species were captured within the rockweed habitat. Long term removal of this habitat may affect the foraging, refuge, and reproduction of tidepool fish species. Further research on these interesting and/or commercially valuable fishes is needed to assess the importance of this natural resource on the coast of Maine.

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APPENDICES

APPENDIX A

PHYSICAL CHARACTERISTICS AND SAMPLING DATA FOR EACH TIDEPOOL

TABLE A.1

PHYSICAL CHARACTERISTICS OF TIDEPOOLS WITH IDENTITY AND LENGTH OF FISHES CAPTURED FOR EACH SAMPLE FROM JUNE-SEPTEMBER 2001

Site	Pool	Treatment	Map Coordinates	Surface area (m^2)	Average depth (m)	Dominant substrate	Sample	Date	Time	Habitat	Fish species (n)	Lengths (cm)
GW	1	HALF CUT	44°28'15.8'' N	7.04	0.25	MIXED	1	6/27	10:00	POOL	0	
			67°33'41.7''W							FRINGE	0	
							2	7/10	7:30	POOL	*C. lumpus* (2)	1.5, 1.3
										FRINGE	0	
							3	7/19	15:45	POOL	*C. lumpus* (4)	1.2, 0.9, 1.8, 2.5
											L. atlanticus (1)	1.4
										FRINGE	0	
							4	8/7	8:45	POOL	*C. lumpus* (7)	2.0, 1.5, 0.4, 1.6, 2.6, 0.4, 0.5
										FRINGE	0	
							5	8/20	17:15	POOL	*C. lumpus* (3)	0.6, 2.5, 2.0
										FRINGE	0	
							6	8/28	14:15	POOL	*C. lumpus* (2)	1.1, 3.8
										FRINGE	0	
							7	9/16	16:45	POOL	*C. lumpus* (2)	4.0, 2.5
										FRINGE	0	
	2	FULL CUT	44°28'16.6'' N	21.40	0.29	BROWN	1	6/26	11:30	POOL	0	
			67°33'43.6''W							FRINGE	0	
							2	7/10	8:30	POOL	0	
										FRINGE	*P. gunnellus* (1)	17.0
							3	7/19	16:40	POOL	0	
										FRINGE	0	
							4	8/7	9:15	POOL	0	
										FRINGE	0	
							5	8/21	8:15	POOL	0	
										FRINGE	0	
							6	8/28	14:30	POOL	0	
										FRINGE	0	
							7	9/16	16:20	POOL	0	
										FRINGE	0	

Site	Pool	Treatment	Map Coordinates	Surface area (m^2)	Average depth (m)	Dominant substrate	Sample	Date	Time	Habitat	Fish species (n)	Lengths (cm)
	3	HALF CUT	44°28'17.5" N 67°33'45.3"W	21.92	0.22	BROWN	1	6/27	10:00	POOL	*C. lumpus* (10)	0.5, 0.8, 1.0, 0.9, 0.9, 0.4, 0.5, 0.6, 0.3, 0.6
										FRINGE	0	
							2	7/10	9:30	POOL	*C. lumpus* (15)	1.5, 0.9, 0.9, 1.3, 0.9, 0.9, 0.9, 0.9, 0.9, 0.9, 0.9, 0.9, 0.9, 0.9, 0.3
										FRINGE	0	
							3	7/20	18:00	POOL	*C. lumpus* (7)	1.1, 1.1, 0.9, 1.0, 1.1, 0.6, 0.5
										FRINGE	0	
							4	8/7	8:00	POOL	*C. lumpus* (26)	1.3, 1.5, 1.8, 1.0, 1.6, 1.6, 0.9, 1.5, 1.5, 1.8, 1.3, 1.4 1.5, 1.6, 1.4, 1.2, 1.2, 1.4, 0.7, 1.5, 1.4, 1.3, 1.5, 1.5, 1.5, 1.5
										FRINGE	0	
							5	8/20	17:45	POOL	*L. atlanticus* (1)	3.5
											C. lumpus (24)	3.0, 1.2, 1.2, 2.0, 1.9, 1.4, 1.4, 1.6, 2.4, 2.3, 1.6, 1.7 1.1, 1.1, 1.2, 1.7, 2.2, 3.2, 1.7, 1.5, 1.7, 1.2, 2.0, 1.1
										FRINGE	0	
							6	9/3	18:30	POOL	*L. atlanticus* (1)	2.0
											C. lumpus (10)	1.7, 1.5, 2.0, 2.0, 1.5, 2.4, 2.2, 2.0, 1.3, 1.7
										FRINGE	0	
							7	9/16	16:00	POOL	*M. scorpius* (1)	6.0
											P. gunnellus (1)	5.1
											L. atlanticus (1)	5.1, 5.4
											C. lumpus (7)	2.6, 2.0, 2.6, 2.1, 2.9, 1.7, 2.9
										FRINGE	0	

Site	Pool	Treatment	Map Coordinates	Surface area (m^2)	Average depth (m)	Dominant substrate	Sample	Date	Time	Habitat	Fish species (n)	Lengths (cm)
	4	NO CUT	44°28'17.4'' N 67°33'45.2''W	10.60	0.18	ROCK	1	6/26	12:00	POOL	0	
										FRINGE	0	
							2	7/10	10:30	POOL	0	
										FRINGE	0	
							3	7/19	18:00	POOL	*C. lumpus* (2)	0.5, 0.4
										FRINGE	0	
							4	8/7	10:15	POOL	*C. lumpus* (1)	0.9
										FRINGE	0	
							5	8/21	8:45	POOL	*M. scorpius* (1)	3.5
											L. atlanticus (1)	1.0
										FRINGE	0	
							6	8/28	15:00	POOL	0	
										FRINGE	0	
							7	9/16	15:30	POOL	0	
										FRINGE	*M. scorpius* (1)	4.9
	5	NO CUT	44°28'16.2'' N 67°33'45.1''W	25.12	0.32	MIXED	1	6/26	9:00	POOL	*M. scorpius* (1)	2.8
											C. lumpus (1)	0.8
											L. atlanticus (1)	1.3
											P. virens (1)	4.2
											P. gunnellus (1)	3.5
										FRINGE	*M. scorpius* (1)	3.2
							2	7/11	9:30	POOL	*M. scorpius* (2)	4.3, 4.3
											C. lumpus (1)	1.3
											C. harengus (9)	5.6, 4.6, 5.5, 5.2, 5.2, 5.7, 5.2, 5.0, 6.0
										FRINGE	*P. gunnellus* (1)	14.9
							3	7/19	14:15	POOL	*M. scorpius* (2)	4.6, 3.7
											P. gunnellus (1)	4.5
										FRINGE	*P. gunnellus* (1)	18.6
							4	8/7	6:45	POOL	*C. lumpus* (1)	1.2
											L. atlanticus (1)	3.5
											P. gunnellus (1)	3.8
										FRINGE	0	
							5	8/20	16:00	POOL	*M. scorpius* (5)	6.0, 4.6, 3.9, 4.5, 4.3
											M. aenaeus (1)	3.4
										FRINGE	0	

Site	Pool	Treatment	Map Coordinates	Surface area (m^2)	Average depth (m)	Dominant substrate	Sample	Date	Time	Habitat	Fish species (n)	Lengths (cm)
							6	8/28	13:00	POOL	*M. scorpius* (2)	4.3, 4.2
											P. gunnellus (1)	5.0
										FRINGE	*M. scorpius* (1)	5.7
							7	9/16	14:45	POOL	*M. scorpius* (1)	6.5
											M. aenaeus (1)	6.5
											L. atlanticus (5)	4.0, 5.8, 5.6, 5.5, 4.0
											C. lumpus (2)	3.8, 4.5
										FRINGE	0	
	6	FULL CUT	44°28'20.5" N 67°33'58.2"W	4.56	0.15	ROCK	1	6/27	11:10	POOL	0	
										FRINGE	0	
							2	7/9	7:00	POOL	0	
										FRINGE	0	
							3	7/20	19:30	POOL	0	
										FRINGE	0	
							4	8/7	18:15	POOL	0	
										FRINGE	0	
							5	8/21	9:30	POOL	0	
										FRINGE	0	
							6	9/3	18:00	POOL	0	
										FRINGE	0	
							7	9/28	15:15	POOL	0	
										FRINGE	0	
	7	FULL CUT	44°28'18.6" N 67°33'55.5"W	9.28	0.12	MIXED	1	6/27	11:45	POOL	0	
										FRINGE	0	
							2	7/9	8:00	POOL	*C. lumpus* (3)	0.5, 0.8, 0.3
										FRINGE	*C. lumpus* (2)	0.6, 0.5
											P. gunnellus (1)	12.3
							3	7/20	17:00	POOL	*C. lumpus* (1)	1.0
										FRINGE	0	
							4	8/7	18:45	POOL	0	
										FRINGE	0	
							5	8/21	18:00	POOL	*C. lumpus* (1)	1.6
										FRINGE	0	
							6	9/3	17:45	POOL	0	
										FRINGE	0	
							7	9/28	15:00	POOL	0	
										FRINGE	0	

Site	Pool	Treatment	Map Coordinates	Surface area (m^2)	Average depth (m)	Dominant substrate	Sample	Date	Time	Habitat	Fish species (n)	Lengths (cm)
	8	HALF CUT	44°28'16.9'' N 67°33'57.8''W	5.24	0.17	ROCK	1	6/27	10:00	POOL	*C. lumpus* (3)	0.4, 0.5, 1.0
										FRINGE	*C. lumpus* (1)	0.4
							2	7/9	9:00	POOL	0	
										FRINGE	0	
							3	7/20	16:00	POOL	0	
										FRINGE	0	
							4	8/7	18:00	POOL	0	
										FRINGE	0	
							5	8/21	10:00	POOL	0	
										FRINGE	0	
							6	9/3	7:15	POOL	0	
										FRINGE	0	
							7	9/28	15:30	POOL	0	
										FRINGE	0	
	9	NO CUT	44°28'17.8'' N 67°34'07.3''W	93.76	0.20	MIXED	1	6/27	12:20	POOL	0	
										FRINGE	0	
							2	7/10	6:30	POOL	*M. scorpius* (2) *M. aenaeus* (1)	3.2, 4.0 3.9
										FRINGE	0	
							3	7/20	14:10	POOL	*M. scorpius* (2) *C. lumpus* (2)	5.2, 2.7 1.2, 1.2
										FRINGE	0	
							4	8/7	19:15	POOL	0	
										FRINGE	0	
							5	8/21	16:45	POOL	*G. aculeatus* (1)	7.5
										FRINGE	*M. scorpius* (2)	4.6, 4.8
							6	9/3	16:15	POOL	*G. aculeatus* (2) *L. atlanticus* (1)	10, 5.5 0.7
										FRINGE	0	
							7	9/16	13:30	POOL	*M. aenaeus* (1)	6.6
										FRINGE	0	
Q	1	HALF CUT	44°48'43.6'' N 66°57'09.7''W	13.36	0.35	BROWN	1	6/24	7:00	POOL	0	
										FRINGE	*P. gunnellus* (1)	12.0
							2	7/9	19:00	POOL	0	
										FRINGE	0	
							3	7/23	18:45	POOL	0	
										FRINGE	*M. scorpius* (1)	4.5
							4	8/1	14:30	POOL	*M. scorpius* (2) *L. atlanticus* (2)	5.2, 4.1 8.2, 2.3

Site	Pool	Treatment	Map Coordinates	Surface area (m^2)	Average depth (m)	Dominant substrate	Sample	Date	Time	Habitat	Fish species (n)	Lengths (cm)
										FRINGE	0	
							5	8/16	13:45	POOL	*M. scorpius* (1)	3.2
											L. atlanticus (2)	3.0, 1.8
										FRINGE	0	
							6	9/2	17:00	POOL	*M. scorpius* (3)	4.6, 5.5, 3.6
										FRINGE	*P. gunnellus* (1)	14.5
							7	9/15	15:45	POOL	0	
										FRINGE	*M. scorpius* (1)	5.1
	2	FULL CUT	44°48'44.4" N 66°57'08.9"W	11.04	0.25	BROWN	1	6/24	8:00	POOL	0	
										FRINGE	0	
							2	7/9	20:00	POOL	0	
										FRINGE	*P. gunnellus* (1)	11.0
							3	7/23	17:45	POOL	*C. lumpus* (1)	1.0
										FRINGE	0	
							4	8/1	15:30	POOL	*P. gunnellus* (1)	16.1
										FRINGE	0	
							5	8/16	12:45	POOL	*C. lumpus* (1)	1.5
										FRINGE	0	
							6	9/2	17:45	POOL	0	
										FRINGE	0	
							7	9/15	15:15	POOL	*M. aenaeus* (1)	3.5
											L. atlanticus (1)	0.9
										FRINGE	0	
	3	NO CUT	44°48'45.6" N 66°57'07.2"W	9.56	0.19	MIXED	1	6/24	9:00	POOL	*L. atlanticus* (2)	7.0, 7.5
										FRINGE	*M. scorpius* (1)	2.0
							2	7/10	20:00	POOL	0	
										FRINGE	0	
							3	7/23	8:30	POOL	*M. scorpius* (5)	3.9, 3.4, 3.3, 3.9, 3.5
											C. lumpus (1)	0.8
										FRINGE	0	
							4	8/1	16:10	POOL	*M. scorpius* (1)	3.5
										FRINGE	0	
							5	8/16	14:30	POOL	*M. scorpius* (1)	5.0
											C. lumpus (1)	1.7
											L. atlanticus (1)	3.2
										FRINGE	0	
							6	9/1	18:00	POOL	*M. scorpius* (1)	4.0
											C. lumpus (1)	2.0

Site	Pool	Treatment	Map Coordinates	Surface area (m^2)	Average depth (m)	Dominant substrate	Sample	Date	Time	Habitat	Fish species (n)	Lengths (cm)
											L. atlanticus (3)	3.0, 3.2, 3.3
										FRINGE	0	
							7	9/15	14:30	POOL	*M. scorpius* (2)	3.5, 4.2
										FRINGE	0	
	4	HALF CUT	44°48'46.9" N 66°57'06.8"W	33.28	0.27	MIXED	1	9/25	7:00	POOL	*M. scorpius* (1)	2.7
										FRINGE	*L. atlanticus* (1)	7.6
											P. gunnellus (1)	9.1
							2	7/10	18:30	POOL	*M. scorpius* (1)	2.8
										FRINGE	0	
							3	7/23	6:45	POOL	*M. scorpius* (1)	4.1
										FRINGE	0	
							4	8/1	16:50	POOL	*M. scorpius* (1)	3.0
											M. aenaeus (1)	4.4
										FRINGE	0	
							5	8/16	15:30	POOL	*M. scorpius* (3)	3.7, 3.9, 5.0
											M. aenaeus (1)	4.0
										FRINGE	0	
							6	9/2	18:15	POOL	*M. scorpius* (1)	3.7
											L. atlanticus (2)	3.0, 3.1
											C. lumpus (4)	2.1, 1.6, 2.5, 1.6
										FRINGE	*M. scorpius* (2)	3.7, 4.4
							7	9/15	14:00	POOL	*C. lumpus* (4)	2.6, 2.7, 2.8, 2.9
											L. atlanticus (1)	3.5
										FRINGE	0	
	5	NO CUT	44°48'47.5" N 66°57'06.5"W	25.16	0.17	MIXED	1	6/24	9:40	POOL	*A. rostrata* (1)	2.5
										FRINGE	0	
							2	7/10	19:15	POOL	*M. scorpius* (1)	2.8
										FRINGE	0	
							3	7/23	6:15	POOL	0	
										FRINGE	0	
							4	8/1	17:45	POOL	0	
										FRINGE	0	
							5	8/16	16:00	POOL	*G. aculeatus* (1)	5.4
										FRINGE	0	
							6	9/1	18:30	POOL	0	
										FRINGE	0	
							7	9/15	13:30	POOL	0	

Site	Pool	Treatment	Map Coordinates	Surface area (m^2)	Average depth (m)	Dominant substrate	Sample	Date	Time	Habitat	Fish species (n)	Lengths (cm)
										FRINGE	0	
	6	HALF CUT	44°48'55.6" N 66°56'58.8"W	7.20	0.18	BROWN	1	6/25	10:40	POOL	0	
										FRINGE	0	
							2	7/9	18:00	POOL	*M. scorpius* (1)	3.6
										FRINGE	*P. gunnellus* (2)	9.9, 12.6
							3	7/23	10:00	POOL	0	
										FRINGE	0	
							4	8/2	14:45	POOL	0	
										FRINGE	0	
							5	8/17	17:00	POOL	0	
										FRINGE	0	
							6	9/1	16:00	POOL	0	
										FRINGE	0	
							7	9/15	13:00	POOL	0	
										FRINGE	0	
	7	FULL CUT	44°48'50.5" N 66°56'57.6"W	3.88	0.17	MIXED	1	6/25	8:30	POOL	0	
										FRINGE	0	
							2	7/8	6:00	POOL	*C. lumpus* (1)	0.4
										FRINGE		
							3	7/23	19:45	POOL	0	
										FRINGE	0	
							4	8/2	16:40	POOL	0	
										FRINGE	0	
							5	8/17	15:00	POOL	0	
										FRINGE	0	
							6	9/1	17:20	POOL	0	
										FRINGE	0	
							7	9/17	18:30	POOL	0	
										FRINGE	0	
	8	NO CUT	44°48'51.1" N 66°56'58.6"W	6.44	0.12	GREEN	1	6/25	9:00	POOL	0	
										FRINGE	0	
							2	7/8	7:00	POOL	*C. lumpus* (1)	0.4
											A. americanus (4)	6.1, 5.1, 5.6, 5.5
										FRINGE	0	
							3	7/23	20:15	POOL	*C. lumpus* (7)	1.0, 0.7, 0.5, 0.5, 0.5, 0.7
											G. morhua (1)	6.5
											M. scorpius (1)	2.0
											P. gunnellus (1)	4.0

Site	Pool	Treatment	Map Coordinates	Surface area (m^2)	Average depth (m)	Dominant substrate	Sample	Date	Time	Habitat	Fish species (n)	Lengths (cm)
										FRINGE	0	
							4	8/2	16:00	POOL	*M. aenaeus* (1)	3.2
										FRINGE	0	
							5	8/17	15:20	POOL	*M. scorpius* (2)	3.2, 5.3
											C. lumpus (1)	0.6
										FRINGE	0	
							6	9/1	17:00	POOL	0	
										FRINGE	*C. lumpus* (1)	0.6
							7	9/17	18:15	POOL	0	
										FRINGE	0	
	9	FULL CUT	44°48'53.7" N 66°56'59.6" W	13.64	0.16	GREEN	1	6/25	9:50	POOL	*M. scorpius* (1)	2.0
										FRINGE	0	
							2	7/8	8:00	POOL	0	
										FRINGE	0	
							3	7/23	9:20	POOL	0	
										FRINGE	0	
							4	8/2	15:20	POOL	*C. lumpus* (1)	1.0
										FRINGE	0	
							5	8/17	16:15	POOL	*M. scorpius* (1)	3.6
											C. harengus (1)	7.0
										FRINGE	0	
							6	9/1	16:30	POOL	*M. scorpius* (1)	3.6
										FRINGE	0	
							7	9/17	18:00	POOL	*M. aenaeus* (2)	4.7, 4.8
										FRINGE	0	
S	1	NO CUT	44°20'24.8" N 68°02'37.6" W	23.56	0.19	GREEN	1	6/21	19:15	POOL	0	
										FRINGE	0	
							2	7/7	6:30	POOL	0	
										FRINGE	0	
							3	7/21	7:13	POOL	0	
										FRINGE	0	
							4	8/3	18:00	POOL	0	
										FRINGE	0	
							5	8/15	14:00	POOL	0	
										FRINGE	0	
							6	8/30	14:20	POOL	0	
										FRINGE	0	
							7	9/19	17:30	POOL	0	

Site	Pool	Treatment	Map Coordinates	Surface area (m^2)	Average depth (m)	Dominant substrate	Sample	Date	Time	Habitat	Fish species (n)	Lengths (cm)
										FRINGE	0	
	2	FULL CUT	44°21'34.6" N 68°04'36.9" W	53.6	0.30	ROCK	1	6/22	15:30	POOL	0	
										FRINGE	0	
							2	7/6	16:00	POOL	0	
										FRINGE	0	
							3	7/22	5:30	POOL	0	
										FRINGE	0	
							4	8/3	15:00	POOL	*L. atlanticus* (1)	1.0
										FRINGE	0	
							5	8/15	11:15	POOL	0	
										FRINGE	0	
							6	8/30	12:45	POOL	0	
										FRINGE	0	
							7	9/19	17:00	POOL	0	
										FRINGE	0	
	3	HALF CUT	44°20'06.3" N 68°02'43.5" W	54.4	0.28	ROCK	1	6/22	17:00	POOL	*G. aculeatus* (1)	6.5
										FRINGE	0	
							2	7/6	19:00	POOL	0	
										FRINGE	0	
							3	7/22	18:00	POOL	*C. lumpus* (1)	3.5
											M. scorpius (1)	4.2
										FRINGE	0	
							4	8/8	17:30	POOL	0	
										FRINGE	0	
							5	8/14	13:20	POOL	0	
										FRINGE	*C. lumpus* (1)	1.2
							6	8/31	18:00	POOL	*P. gunnellus* (1)	12.0
											C. lumpus (1)	0.9
										FRINGE	*M. aenaeus* (1)	6.0
							7	9/14	16:20	POOL	0	
										FRINGE	0	
	4	NO CUT	44°20'06.1" N 68°02'44.0" W	5.32	0.19	BROWN	1	6/21	17:15	POOL	0	
										FRINGE	0	
							2	7/6	20:00	POOL	0	
										FRINGE	0	
							3	7/22	19:00	POOL	0	
										FRINGE	0	
							4	8/8	18:00	POOL	0	
										FRINGE	0	

Site	Pool	Treatment	Map Coordinates	Surface area (m^2)	Average depth (m)	Dominant substrate	Sample	Date	Time	Habitat	Fish species (n)	Lengths (cm)
							5	8/14	14:15	POOL	0	
										FRINGE	0	
							6	8/31	17:30	POOL	0	
										FRINGE	0	
							7	9/14	16:00	POOL	0	
										FRINGE	0	
	5	HALF CUT	44°20'05.1" N 68°02'45.0" W	8.68	0.30	MIXED	1	6/22	6:00	POOL	*M. aenaeus* (1)	2.6
										FRINGE	*P. gunnellus* (1)	14.0
							2	7/6	18:00	POOL	*C. lumpus* (1)	0.5
										FRINGE	0	
							3	7/22	8:15	POOL	*L. atlanticus* (6)	0.9, 0.9, 0.9, 0.7, 1.0, 1.0
											C. lumpus (6)	0.7, 1.2, 0.6, 0.7, 0.5, 1.0
										FRINGE	*P. gunnellus* (1)	10.0
											C. lumpus (1)	1.7
							4	8/8	19:00	POOL	*C. lumpus* (2)	1.2, 0.9
											P. gunnellus (1)	10.0
										FRINGE	*M. aenaeus* (1)	6.5
							5	8/14	12:30	POOL	*M. aenaeus* (1)	5.3
										FRINGE	0	
							6	8/31	17:00	POOL	*M. scorpius* (2)	4.0, 4.4
											L. atlanticus (2)	5.1, 4.5
											C. lumpus (1)	1.5
										FRINGE	0	
							7	9/14	15:30	POOL	*M. aenaeus* (1)	6.2
											L. atlanticus (1)	5.1
										FRINGE	*M. scorpius* (1)	5.9
	6	FULL CUT	44°20'02.3" N 68°02'48.8" W	19.6	0.16	GREEN	1	6/22	5:00	POOL	0	
										FRINGE	0	
							2	7/6	17:00	POOL	0	
										FRINGE	0	
							3	7/22	16:45	POOL	0	
										FRINGE	0	
							4	8/8	18:30	POOL	0	
										FRINGE	0	
							5	8/14	12:00	POOL	0	
										FRINGE	0	
							6	8/31	16:30	POOL	0	

Site	Pool	Treatment	Map Coordinates	Surface area (m^2)	Average depth (m)	Dominant substrate	Sample	Date	Time	Habitat	Fish species (n)	Lengths (cm)
										FRINGE	0	
							7	9/14	15:10	POOL	0	
										FRINGE	0	
	7	NO CUT	44°20'20.2'' N 68°02'40.3''W	64.72	0.29	MIXED	1	6/22	18:45	POOL	*P. virens* (1)	5.5
											C. lumpus (1)	1.7
											M. scorpius (2)	3.5, 2.5
											L. atlanticus (4)	1.0, 8.0, 1.0, 1.6
										FRINGE	*M. scorpius* (1)	3.5
											P. gunnellus (1)	10.5
							2	7/7	19:00	POOL	*P. virens* (1)	7.1
											C. lumpus (4)	1.3, 1.4, 1.1, 0.6
											L. atlanticus (3)	2.0, 1.5, 0.8
										FRINGE	*M. scorpius* (1)	4.0
							3	7/21	5:15	POOL	*C. lumpus* (6)	0.5, 0.4, 1.0, 1.7, 0.7, 1.5
											L. atlanticus (7)	1.1, 2.0. 2.5, 2.6, 2.5, 2.2, 1.0
										FRINGE	*M. scorpius* (1)	5.7
							4	8/3	16:00	POOL	*L. atlanticus* (1)	3.6
											C. lumpus (9)	2.0, 1.6, 2.6, 1.5, 2.4, 2.0, 2.5, 1.6, 1.4
										FRINGE	0	
							5	8/15	13:15	POOL	*C. lumpus* (12)	2.4, 3.0, 2.0, 3.1, 1.8, 2.8, 3.0, 1.8, 1.6, 3.2, 2.5, 2.0
											L. atlanticus (2)	3.5, 3.4
										FRINGE	*L. atlanticus* (1)	1.2
							6	8/30	15:15	POOL	*M. scorpius* (1)	5.6
											L. atlanticus (1)	5.0
											C. lumpus (8)	2.3, 2.5, 2.1, 4.0, 2.0, 3.0, 2.2, 3.
										FRINGE	0	
							7	9/14	14:00	POOL	*L. atlanticus* (3)	6.8, 4.5, 5.6
											P. gunnellus (1)	5.6
											C. lumpus (1)	2.5

Site	Pool	Treatment	Map Coordinates	Surface area (m^2)	Average depth (m)	Dominant substrate	Sample	Date	Time	Habitat	Fish species (n)	Lengths (cm)
										FRINGE	*M. scorpius* (1)	6.2
											C. lumpus (1)	2.4
	8	FULL CUT	44°20'24.4" N 68°02'37.9" W	20.56	0.17	GREEN	1	6/23	17:15	POOL	0	
										FRINGE	0	
							2	7/7	5:30	POOL	*P. gunnellus* (1)	3.1
										FRINGE	0	
							3	7/21	6:45	POOL	*M. scorpius* (1)	4.2
										FRINGE	0	
							4	8/3	18:30	POOL	0	
										FRINGE	0	
							5	8/15	14:30	POOL	0	
										FRINGE	0	
							6	8/30	14:00	POOL	0	
										FRINGE	0	
							7	9/19	18:00	POOL	0	
										FRINGE	0	
	9	HALF CUT	44°20'24.7" N 68°02'38.1" W	16.52	0.19	GREEN	1	6/21	19:45	POOL	0	
										FRINGE	0	
							2	7/7	7:30	POOL	0	
										FRINGE	0	
							3	7/24	9:00	POOL	0	
										FRINGE	0	
							4	8/3	17:30	POOL	0	
										FRINGE	0	
							5	8/15	15:00	POOL	0	
										FRINGE	0	
							6	8/30	14:40	POOL	0	
										FRINGE	0	
							7	9/19	18:20	POOL	0	
										FRINGE	0	

APPENDIX B

RESULTS OF THE SPLIT PLOT ANOVA FOR INDIVIDUAL SPECIES AND GROUPS

TABLE B.1

RESULTS OF THE SPLIT PLOT ANOVA FOR INDIVIDUAL FISH SPECIES AND NOTATION OF SIGNIFICANT F-TESTS. SOURCES OF VARIATION ARE AS FOLLOWS: S=SITE, T=TREATMENT, B=BEFORE AND AFTER TREATMENT, R=ROCKWEED VS OTHER TIDEPOOL HABITAT, P=POOL

Species	Source	Sum-of Squares	df	p-value
Cyclopterus lumpus	S	5.526	2	0.000
	T	2.274	2	0.002
	B	0.005	1	0.872
	*R	6.535	1	0.000
	T x B	0.029	2	0.922
	T x R	2.158	2	0.003
	R x B	0.001	1	0.945
	T x R x B	0.118	2	0.718
	P(T)	19.807	16	0.000
	B x P(T)	2.635	16	0.536
	R x P(T)	15.684	16	0.000
	R x B x P(T)	1.632	16	0.901
	Error	53.169	300	
Liparis atlanticus	S	0.075	2	0.377
	T	1.051	2	0.000
	B	0.001	1	0.857
	*R	1.100	1	0.000
	T x B	0.015	2	0.824
	T x R	0.646	2	0.000
	R x B	0.005	1	0.711
	T x R x B	0.068	2	0.412
	P(T)	5.733	16	0.000
	B x P(T)	0.669	16	0.364
	R x P(T)	3.085	16	0.000
	R x B x P(T)	1.047	16	0.045
	Error	11.513	300	
Myoxocephalus scorpius	S	0.057	2	0.562
	T	0.973	2	0.000
	B	0.004	1	0.781
	*R	0.964	1	0.000
	T x B	0.107	2	0.336
	T x R	0.196	2	0.137
	R x B	0.005	1	0.741
	T x R x B	0.032	2	0.725
	P(T)	2.505	16	0.000
	B x P(T)	0.471	16	0.883
	R x P(T)	1.750	16	0.005

Species	Source	Sum-of Squares	df	p-value
Myoxocephalus scorpius	R x B x P(T)	0.943	16	0.265
(cont.)	Error	14.725	300	
Pholis gunnellus	S	0.033	2	0.345
	T	0.011	2	0.700
	*B	0.052	1	0.068
	*R	0.001	1	0.846
	T x B	0.002	2	0.941
	T x R	0.050	2	0.204
	R x B	0.077	1	0.026
	T x R x B	0.081	2	0.076
	P(T)	0.431	16	0.040
	B x P(T)	0.242	16	0.484
	R x P(T)	0.200	16	0.681
	R x B x P(T)	0.248	16	0.456
	Error	4.655	300	

* Indicates independent variables which resulted in significant values for individual hypotheses tests (F-tests), $\alpha = 0.05$

TABLE B.2

RESULTS OF THE SPLIT PLOT ANOVA FOR INDIVIDUAL INVERTEBRATE GROUPS AND NOTATION OF SIGNIFICANT F-TESTS. SOURCES OF VARIATION ARE AS FOLLOWS: S=SITE, T=TREATMENT, B=BEFORE AND AFTER TREATMENT, R=ROCKWEED VS TIDEPOOL HABITAT, P=POOL

Group	Source	Sum-of Squares	df	p-value
Isopoda	S	88.698	2	0.000
	T	43.241	2	0.000
	B	0.009	1	0.952
	R	0.548	1	0.628
	T x B	0.053	2	0.989
	T x R	1.468	2	0.730
	R x B	0.048	1	0.886
	T x R x B	3.184	2	0.506
	P(T)	297.45	16	0.000
	B x P(T)	51.281	16	0.152
	R x P(T)	31.645	16	0.629
	R x B x P(T)	30.998	16	0.649
	Error	699.102	300	
Amphipoda	S	211.072	2	0.000
	T	69.691	2	0.000
	B	0.033	1	0.893
	*R	29.747	1	0.000
	T x B	4.759	2	0.276
	T x R	4.873	2	0.267
	*R x B	18.663	1	0.002
	T x R x B	2.465	2	0.512
	P(T)	203.632	16	0.000
	B x P(T)	37.057	16	0.222
	R x P(T)	54.101	16	0.026
	R x B x P(T)	26.801	16	0.557
	Error	551.603	300	
Copepoda	S	148.008	2	0.000
	T	58.818	2	0.000
	*B	47.124	1	0.000
	*R	200.801	1	0.000
	T x B	3.329	2	0.445
	T x R	2.056	2	0.607
	*R x B	20.820	1	0.002
	T x R x B	1.498	2	0.695
	P(T)	218.758	16	0.000
	B x P(T)	71.258	16	0.006
	R x P(T)	26.949	16	0.662
	R x B x P(T)	14.279	16	0.973

Group	Source	Sum-of Squares	df	p-value
Copepoda (cont.)	Error	615.824	300	
Acarina	S	107.154	2	0.000
	T	3.676	2	0.278
	B	0.381	1	0.606
	*R	26.836	1	0.000
	T x B	5.445	2	0.151
	*T x R	9.539	2	0.037
	*R x B	5.048	1	0.061
	T x R x B	4.172	2	0.234
	P(T)	109.081	16	0.000
	B x P(T)	23.509	16	0.426
	R x P(T)	20.418	16	0.578
	R x B x P(T)	15.734	16	0.805
	Error	428.634	300	
Cunio spp. Larvae	S	40.897	2	0.000
	T	8.043	2	0.157
	B	5.325	1	0.117
	R	7.550	1	0.063
	T x B	1.598	2	0.691
	T x R	2.747	2	0.530
	*R x B	27.066	1	0.000
	T x R x B	7.671	2	0.171
	P(T)	143.444	16	0.000
	B x P(T)	56.412	16	0.060
	R x P(T)	30.752	16	0.582
	R x B x P(T)	61.999	16	0.031
	Error	648.122	300	
Eggs	S	214.127	2	0.000
	T	25.043	2	0.022
	*B	28.380	1	0.003
	*R	433.970	1	0.000
	T x B	10.554	2	0.197
	T x R	8.537	2	0.269
	*R x B	36.722	1	0.001
	T x R x B	6.849	2	0.348
	P(T)	229.907	16	0.000
	B x P(T)	78.040	16	0.095
	R x P(T)	42.819	16	0.654
	R x B x P(T)	16.297	16	0.995
	Error	969.772	300	

* Indicates independent variables which resulted in significant values for individual hypotheses tests (F-tests), $\alpha = 0.05$

APPENDIX C

INVERTEBRATE DATA

TABLE C.1

INVERTEBRATE COUNTS FOR EACH POOL PER SAMPLE, IN ROCKWEED AND OTHER TIDEPOOL HABITATS

Sample	Site	Pool	Rockweed (R)/ Tidepool (D)	Cir	Iso	Amp	Mys	Dec	Cop	Aca	Pol	Ter	Lar	Egg	Total**
1	GW	1	D	0	0	308	0	0	52	28	0	0	4	0	392
1	GW	1	R	0	0	280	0	0	136	60	4	0	4	20	504
1	GW	2	D	0	4	8	0	0	152	92	4	0	12	20	292
1	GW	2	R	0	0	12	0	0	120	20	0	0	4	0	156
1	GW	3	D	0	48	96	0	0	2128	64	16	0	32	80	2464
1	GW	3	R	0	8	32	0	0	720	300	0	0	104	92	1256
1	GW	4	D	0	64	144	64	0	9024	80	0	0	112	1968	11456
1	GW	4	R	0	0	144	64	0	9488	0	0	0	32	160	9888
1	GW	5	D	64	256	256	0	0	8320	64	0	0	0	320	9280
1	GW	5	R	0	16	272	0	0	1392	96	0	0	32	160	1968
1	GW	6	D	128	192	0	0	0	2112	64	0	0	0	2432	4928
1	GW	6	R	0	512	0	0	0	3584	256	0	0	0	2816	7168
1	GW	7	D	56	8	132	4	0	132	176	0	0	8	980	1496
1	GW	7	R	0	12	24	0	0	304	92	0	0	4	28	464
1	GW	8	D	64	96	80	0	0	3968	320	0	0	80	4320	8928
1	GW	8	R	0	144	80	0	0	1248	576	0	0	0	208	2256
1	GW	9	D	0	128	128	0	0	1088	256	0	0	64	1472	3136
1	GW	9	R	64	832	512	0	0	1792	128	0	0	0	448	3776
1	Q	1	D	4	0	0	0	0	56	40	0	0	4	4	108
1	Q	1	R	0	0	0	0	0	8	16	0	0	4	0	28
1	Q	2	D	32	0	0	0	0	48	48	0	0	0	48	176
1	Q	2	R	0	0	0	0	0	8	24	4	0	0	28	64
1	Q	3	D	4	0	0	0	0	92	68	0	0	8	76	248
1	Q	3	R	4	0	0	0	4	28	60	0	0	28	0	124
1	Q	4	D	0	0	0	0	0	48	352	0	0	352	0	752
1	Q	4	R	0	0	16	0	0	192	286	0	0	80	256	830
1	Q	5	D	32	0	32	0	0	384	128	0	0	48	80	704
1	Q	5	R	0	0	1	0	0	14	18	0	0	4	3	40

Sample	Site	Pool	Habitat	Cir	Iso	Amp	Mys	Dec	Cop	Aca	Pol	Ter	Lar	Egg	Total**
1	Q	6	D	32	0	0	0	0	288	48	0	0	32	16	416
1	Q	6	R	0	0	0	0	0	160	0	0	0	16	0	176
1	Q	7	D	0	0	4	0	0	76	40	0	0	120	20	264
1	Q	7	R	0	0	8	0	0	40	48	0	0	20	0	116
1	Q	8	D	0	0	0	0	0	32000	320	0	0	0	0	32320
1	Q	8	R	16	0	32	16	0	6912	64	0	0	80	128	7248
1	Q	9	D	0	0	80	0	0	846	288	0	0	0	48	1262
1	Q	9	R	0	0	0	0	0	1008	48	0	0	48	48	1152
1	S	1	D	16	0	32	0	0	96	96	0	0	32	224	496
1	S	1	R	0	0	12	0	0	24	52	0	0	8	12	108
1	S	2	D	192	0	0	0	0	576	192	0	0	0	6656	7616
1	S	2	R	96	32	244	0	0	96	0	0	0	16	432	916
1	S	3	D	128	32	96	0	0	48	144	16	0	16	2144	2624
1	S	3	R	48	0	32	0	0	0	0	144	0	0	416	736
1	S	4	D	28	8	0	0	0	12	12	0	0	12	20	92
1	S	4	R	0	0	12	0	0	20	12	0	0	12	20	76
1	S	5	D	48	0	176	0	0	528	112	0	0	36	256	1156
1	S	5	R	32	0	160	0	0	432	176	0	0	64	160	1024
1	S	6	D	16	0	24	0	0	52	24	0	0	0	144	260
1	S	6	R	0	0	4	0	0	28	40	0	0	0	12	84
1	S	7	D	0	0	0	0	0	0	0	0	0	16	32	48
1	S	7	R	48	0	32	0	0	528	176	0	0	32	160	976
1	S	8	D	112	0	112	0	0	192	64	0	0	32	112	624
1	S	8	R	120	0	28	0	0	76	48	8	0	0	96	376
1	S	9	D	32	4	16	0	0	20	8	0	4	0	184	268
1	S	9	R	48	16	32	0	0	48	64	0	0	0	16	224
2	GW	1	D	8	12	2280	0	0	120	164	0	0	4	376	2968
2	GW	1	R	0	21	1812	0	0	36	116	0	0	0	8	1993
2	GW	2	D	4	16	142	0	0	352	300	4	0	64	180	1062
2	GW	2	R	0	1	56	0	0	112	108	0	0	5	8	290
2	GW	3	D	0	24	156	0	0	1460	512	0	0	68	232	2452
2	GW	3	R	0	16	27	0	0	772	228	0	0	104	72	1219
2	GW	4	D	16	20	18	1	0	6304	256	0	0	160	640	7415
2	GW	4	R	0	13	15	0	0	736	360	0	0	64	8	1196

Sample	Site	Pool	Habitat	Cir	Iso	Amp	Mys	Dec	Cop	Aca	Pol	Ter	Lar	Egg	Total**
2	GW	5	D	32	6	307	0	16	13328	288	0	0	96	1440	15513
2	GW	5	R	0	3	471	0	0	1840	192	0	0	80	80	2666
2	GW	6	D	0	640	0	0	0	6656	2304	0	0	0	3136	12736
2	GW	6	R	16	896	281	0	0	5792	272	0	0	112	1712	9081
2	GW	7	D	32	256	547	0	0	2064	1312	32	0	48	3440	7731
2	GW	7	R	12	528	196	4	4	948	1132	0	0	20	296	3140
2	GW	8	D	16	16	260	0	4	356	232	0	8	0	800	1692
2	GW	8	R	32	16	152	0	0	388	156	0	8	0	140	892
2	GW	9	D	320	2048	1856	192	0	31872	192	0	0	0	19200	55744
2	GW	9	R	0	3328	640	384	64	3648	192	0	0	0	384	8640
2	Q	1	D	4	4	68	0	0	164	232	4	0	4	0	480
2	Q	1	R	4	0	39	0	0	36	76	0	0	8	0	163
2	Q	2	D	8	0	32	0	0	72	112	8	0	8	48	288
2	Q	2	R	4	0	4	0	0	20	76	0	0	4	12	120
2	Q	3	D	4	8	12	0	0	916	204	4	0	20	28	1196
2	Q	3	R	0	4	20	0	0	108	124	4	0	28	0	288
2	Q	4	D	64	64	1	0	0	9640	1408	128	0	384	320	12009
2	Q	4	R	0	12	32	0	0	348	552	8	0	76	12	1040
2	Q	5	D	8	0	12	0	0	348	208	0	4	88	52	720
2	Q	5	R	8	0	20	0	0	164	496	4	0	172	12	876
2	Q	6	D	8	16	16	0	0	204	96	0	0	20	8	368
2	Q	6	R	0	4	11	0	0	48	52	0	0	12	12	139
2	Q	7	D	0	0	4	0	0	88	60	0	0	4	68	228
2	Q	7	R	0	0	0	0	0	44	20	1	0	4	0	69
2	Q	8	D	0	64	2	0	0	78208	128	0	0	0	0	78402
2	Q	8	R	0	4	8	0	0	13024	92	0	0	160	0	13288
2	Q	9	D	0	16	1	16	0	6544	112	0	0	0	48	6737
2	Q	9	R	0	0	2	0	0	2896	56	0	0	28	4	2986
2	S	1	D	4	0	143	0	8	228	64	0	0	8	24	479
2	S	1	R	8	12	170	0	0	8	16	0	0	4	0	218
2	S	2	D	132	4	41	0	0	476	4	0	0	8	1988	2653
2	S	2	R	84	0	94	0	0	60	8	0	0	4	392	642
2	S	3	D	336	48	48	0	0	368	80	0	0	48	3808	4736
2	S	3	R	40	120	114	0	0	116	216	4	0	4	540	1154
2	S	4	D	4	12	5	0	0	28	60	0	0	0	528	637
2	S	4	R	4	4	11	0	0	24	36	0	0	0	40	119

Sample	Site	Pool	Habitat	Cir	Iso	Amp	Mys	Dec	Cop	Aca	Pol	Ter	Lar	Egg	Total**
2	S	5	D	48	32	272	0	1	976	144	0	0	0	928	2401
2	S	5	R	12	8	122	0	3	228	172	4	0	4	28	581
2	S	6	D	4	0	8	0	0	96	56	4	4	0	328	504
2	S	6	R	12	4	9	0	0	48	56	0	0	0	112	241
2	S	7	D	176	48	1024	0	32	848	432	0	0	0	1568	4176
2	S	7	R	0	48	60	0	0	92	224	0	0	0	8	432
2	S	8	D	40	0	64	0	16	300	64	0	0	4	376	900
2	S	8	R	12	0	32	0	4	44	32	4	0	0	8	148
2	S	9	D	8	12	92	0	0	104	12	0	0	0	520	752
2	S	9	R	4	0	179	0	0	28	0	0	0	0	48	259
3	GW	1	D	24	0	216	0	0	96	148	0	0	12	40	536
3	GW	1	R	24	8	76	0	0	108	100	4	0	12	16	348
3	GW	2	D	24	16	88	0	0	116	144	0	0	44	80	512
3	GW	2	R	8	0	20	0	0	64	152	0	0	12	8	264
3	GW	3	D	48	80	144	0	0	1232	1488	0	0	64	480	3536
3	GW	3	R	8	76	76	0	0	444	1260	4	0	64	32	1964
3	GW	4	D	0	48	80	16	0	672	304	0	16	0	224	1360
3	GW	4	R	64	112	64	0	0	128	528	0	64	0	400	1360
3	GW	5	D	3008	0	384	0	0	896	256	0	0	0	960	5504
3	GW	5	R	1008	16	64	0	0	128	272	0	16	64	80	1648
3	GW	6	D	0	256	0	0	0	3072	1792	0	0	0	2560	8192
3	GW	6	R	48	912	32	0	16	672	304	0	0	80	480	2544
3	GW	7	D	128	0	128	0	0	1280	1664	0	0	0	7582	10782
3	GW	7	R	4	420	92	0	0	64	952	4	0	8	8	1552
3	GW	8	D	240	8	12	0	0	16	80	0	0	0	644	1000
3	GW	8	R	152	12	36	0	0	56	168	0	36	8	5	473
3	GW	9	D	0	768	832	0	0	1152	256	0	0	0	2240	5248
3	GW	9	R	80	1232	784	16	0	192	80	0	0	0	560	2944
3	Q	1	D	64	0	8	0	0	16	48	0	0	0	12	148
3	Q	1	R	16	0	12	0	0	84	76	1	0	8	12	209
3	Q	2	D	8	0	28	0	0	52	24	0	0	12	20	144
3	Q	2	R	0	0	0	0	0	12	64	0	0	16	0	92
3	Q	3	D	0	0	48	0	0	2992	176	0	0	48	0	3264
3	Q	3	R	0	8	4	0	0	272	84	0	0	56	0	424
3	Q	4	D	0	80	16	0	0	1232	288	0	0	0	0	1616
3	Q	4	R	0	0	0	0	0	144	196	0	0	56	0	396

Sample	Site	Pool	Habitat	Cir	Iso	Amp	Mys	Dec	Cop	Aca	Pol	Ter	Lar	Egg	Total**
3	Q	5	D	4	0	0	0	0	1112	16	0	0	0	16	1152
3	Q	5	R	0	4	8	0	0	212	50	0	0	548	0	1022
3	Q	6	D	0	4	8	0	0	72	80	0	0	56	0	220
3	Q	6	R	0	8	8	0	0	40	44	4	0	56	16	176
3	Q	7	D	8	0	16	0	0	156	116	0	0	20	0	316
3	Q	7	R	0	4	16	0	0	24	40	0	0	8	0	92
3	Q	8	D	0	0	20	0	0	1124	16	0	12	0	0	1172
3	Q	8	R	0	0	32	0	0	1072	60	0	4	20	0	1188
3	Q	9	D	16	0	64	0	0	560	208	32	0	32	320	1232
3	Q	9	R	0	0	8	0	0	76	108	0	0	48	0	240
3	S	1	D	0	0	176	0	0	368	32	0	0	0	0	576
3	S	1	R	0	4	132	0	0	68	40	0	0	0	8	252
3	S	2	D	48	16	176	0	0	1408	32	0	0	0	3680	5360
3	S	2	R	4	20	80	0	0	360	124	0	0	0	132	720
3	S	3	D	160	176	176	0	0	112	80	80	0	80	1136	2000
3	S	3	R	44	80	104	0	0	20	56	0	0	8	96	408
3	S	4	D	36	12	12	0	0	24	36	0	0	0	196	316
3	S	4	R	32	0	8	0	0	16	28	0	0	0	12	96
3	S	5	D	4	8	48	0	0	116	48	0	0	0	120	344
3	S	5	R	4	12	44	0	0	0	60	0	0	0	20	204
3	S	6	D	8	4	48	0	0	48	28	0	0	8	96	240
3	S	6	R	4	0	20	0	0	0	68	0	0	8	1	185
3	S	7	D	220	28	1504	4	0	296	36	0	0	0	176	2264
3	S	7	R	0	128	272	0	0	432	576	0	0	0	160	1568
3	S	8	D	0	0	56	0	8	164	40	4	0	0	8	280
3	S	8	R	20	0	32	0	0	52	52	0	4	0	0	160
3	S	9	D	12	4	92	0	0	144	28	0	0	4	40	324
3	S	9	R	0	0	156	0	0	8	12	0	0	0	40	216
4	GW	1	D	20	4	116	0	0	182	224	0	0	12	40	598
4	GW	1	R	0	0	16	0	0	32	100	0	0	8	0	156
4	GW	2	D	20	4	48	0	0	140	60	0	0	44	100	416
4	GW	2	R	8	0	32	0	0	36	84	0	0	4	8	172
4	GW	3	D	48	32	192	16	0	848	384	0	0	0	400	1920
4	GW	3	R	4	24	20	0	0	196	764	4	0	0	16	1028
4	GW	4	D	48	32	176	0	0	2112	304	0	0	48	160	2880
4	GW	4	R	0	96	40	0	0	468	296	4	0	8	120	1032

Sample	Site	Pool	Habitat	Cir	Iso	Amp	Mys	Dec	Cop	Aca	Pol	Ter	Lar	Egg	Total**
4	GW	5	D	24	0	88	0	0	1308	0	0	0	0	192	1632
4	GW	5	R	24	0	88	0	0	1308	24	508	0	24	20	1996
4	GW	6	D	0	0	0	256	0	8704	1024	0	0	512	14848	25344
4	GW	6	R	128	320	128	128	0	1472	704	0	0	0	13760	16768
4	GW	7	D	48	256	304	64	0	1056	1360	0	0	32	8800	11920
4	GW	7	R	16	16	28	0	0	36	212	0	0	8	324	640
4	GW	8	D	96	24	44	4	0	80	156	0	0	4	440	848
4	GW	8	R	48	28	8	0	0	68	144	0	0	0	0	296
4	GW	9	D	0	64	576	64	0	896	64	0	0	0	9600	11328
4	GW	9	R	42	976	688	32	16	112	112	0	0	0	128	2106
4	Q	1	D	0	8	12	0	0	36	168	0	0	12	1	237
4	Q	1	R	0	8	16	0	0	8	24	0	0	0	0	56
4	Q	2	D	20	12	4	0	0	60	64	0	0	44	76	280
4	Q	2	R	0	20	0	0	0	4	0	0	0	0	0	24
4	Q	3	D	12	4	100	0	0	1144	112	8	0	16	32	1428
4	Q	3	R	0	0	0	0	0	60	64	0	32	20	0	176
4	Q	4	D	20	0	8	0	0	472	142	0	0	28	24	694
4	Q	4	R	0	4	8	0	0	76	84	8	16	0	4	200
4	Q	5	D	48	16	64	0	0	3296	224	0	1	16	80	3745
4	Q	5	R	0	0	12	0	0	704	76	0	0	32	12	836
4	Q	6	D	4	4	4	0	0	76	68	4	0	8	4	172
4	Q	6	R	4	0	12	0	0	12	40	0	0	12	4	84
4	Q	7	D	8	0	4	0	0	72	44	0	0	24	12	164
4	Q	7	R	0	0	4	0	0	0	4	0	0	4	0	12
4	Q	8	D	0	0	80	0	0	1856	144	0	0	32	240	2352
4	Q	8	R	0	0	4	0	0	80	52	0	0	28	4	168
4	Q	9	D	32	0	112	0	0	528	240	16	0	32	80	1040
4	Q	9	R	8	0	8	0	0	32	20	0	0	0	4	72
4	S	1	D	12	4	40	0	0	340	56	4	4	0	80	544
4	S	1	R	4	4	136	0	0	48	132	0	0	0	12	336
4	S	2	D	208	32	48	0	0	576	48	0	0	0	3200	4208
4	S	2	R	64	0	12	0	0	124	8	0	12	8	1112	1404
4	S	3	D	128	48	128	0	0	208	112	0	0	0	4000	4624
4	S	3	R	16	144	92	0	0	40	60	4	0	0	152	508
4	S	4	D	40	16	32	0	0	96	76	4	0	0	212	476
4	S	4	R	16	0	24	0	0	20	52	0	0	0	12	124

Sample	Site	Pool	Habitat	Cir	Iso	Amp	Mys	Dec	Cop	Aca	Pol	Ter	Lar	Egg	Total**
4	S	5	D	16	0	40	0	0	280	104	0	0	12	164	624
4	S	5	R	8	24	456	0	0	48	716	4	0	0	28	1284
4	S	6	D	48	224	832	0	0	1312	224	32	0	0	2000	4672
4	S	6	R	24	4	8	0	0	40	8	0	0	0	24	116
4	S	7	D	320	0	640	0	0	768	112	0	0	16	1600	3456
4	S	7	R	24	40	8	0	0	120	300	0	0	4	40	536
4	S	8	D	20	16	36	0	0	208	116	0	0	4	160	572
4	S	8	R	36	4	16	0	0	16	16	0	0	0	12	100
4	S	9	D	12	12	88	0	0	196	36	0	0	4	140	488
4	S	9	R	8	20	164	0	0	36	64	4	0	4	0	304
5	GW	1	D	12	4	160	0	0	204	176	8	0	20	32	616
5	GW	1	R	0	0	16	0	0	20	64	0	0	44	0	144
5	GW	2	D	4	28	192	0	0	192	148	4	0	20	240	828
5	GW	2	R	0	8	48	0	0	24	48	0	0	12	8	148
5	GW	3	D	0	64	400	0	0	624	912	0	0	16	688	2720
5	GW	3	R	0	60	60	0	0	152	456	4	0	72	144	948
5	GW	4	D	32	208	192	0	16	2160	160	0	0	80	416	3264
5	GW	4	R	0	140	56	0	4	248	216	0	0	12	0	676
5	GW	5	D	0	1024	0	1024	0	6144	6144	0	0	3072	13312	30720
5	GW	5	R	8	20	28	0	0	212	242	4	0	4	12	530
5	GW	6	D	0	0	0	256	0	3200	2112	0	0	64	5952	11584
5	GW	6	R	0	0	704	0	0	31168	320	0	0	0	7680	39872
5	GW	7	D	96	64	144	0	0	400	432	0	0	0	4160	5296
5	GW	7	R	12	48	8	0	0	28	36	0	0	0	36	168
5	GW	8	D	16	208	176	0	0	134	320	0	0	16	80	950
5	GW	8	R	4	40	80	0	0	40	76	0	0	0	8	248
5	GW	9	D	16	320	352	0	0	80	16	0	0	0	80	864
5	GW	9	R	16	2624	1008	16	0	112	48	0	0	0	64	3888
5	Q	1	D	16	0	64	0	0	88	192	0	0	28	32	420
5	Q	1	R	8	0	20	0	0	4	84	0	4	4	0	124
5	Q	2	D	8	24	24	0	0	192	88	8	0	20	176	540
5	Q	2	R	0	4	0	0	0	12	0	0	0	0	4	20
5	Q	3	D	128	0	128	0	0	4160	512	64	0	320	320	5632
5	Q	3	R	8	0	0	0	0	40	36	0	0	8	0	92
5	Q	4	D	0	0	128	0	0	5248	320	0	0	256	448	6400
5	Q	4	R	8	0	0	0	0	56	68	0	0	36	8	176

Sample	Site	Pool	Habitat	Cir	Iso	Amp	Mys	Dec	Cop	Aca	Pol	Ter	Lar	Egg	Total**
5	Q	5	D	64	128	384	0	0	4480	1344	64	0	0	0	6464
5	Q	5	R	8	8	0	0	0	80	72	0	0	24	0	192
5	Q	6	D	0	4	30	0	4	94	48	0	4	12	16	212
5	Q	6	R	0	4	4	0	0	4	20	0	0	4	0	36
5	Q	7	D	0	0	12	0	0	56	30	0	4	32	40	178
5	Q	7	R	0	4	0	0	0	16	40	0	0	16	8	84
5	Q	8	D	0	0	1536	0	0	5632	1792	0	0	1536	3	10499
5	Q	8	R	0	0	4	0	0	40	24	4	0	28	16	116
5	Q	9	D	64	0	640	0	0	1664	768	0	0	0	960	4096
5	Q	9	R	4	0	0	0	0	24	40	0	4	0	0	72
5	S	1	D	16	0	36	0	0	60	108	0	0	0	48	268
5	S	1	R	12	0	80	0	0	16	36	0	0	0	4	148
5	S	2	D	960	0	128	0	64	3712	192	0	0	256	44800	50240
5	S	2	R	48	12	8	0	0	124	44	36	0	8	220	536
5	S	3	D	384	64	192	0	0	320	192	0	0	0	13440	14592
5	S	3	R	56	56	36	0	0	76	60	0	0	44	100	428
5	S	4	D	20	4	4	0	0	76	20	0	0	4	404	532
5	S	4	R	12	12	8	0	0	36	1	0	0	0	20	89
5	S	5	D	32	48	320	0	0	1296	384	0	0	16	2000	4096
5	S	5	R	20	12	192	0	4	40	92	0	0	12	12	384
5	S	6	D	12	0	20	0	0	288	54	0	0	4	244	754
5	S	6	R	16	0	4	0	0	28	12	0	0	0	12	108
5	S	7	D	464	96	512	0	0	992	80	0	0	32	256	2432
5	S	7	R	148	36	96	0	0	96	56	0	0	8	28	468
5	S	8	D	48	0	48	0	0	256	48	0	0	16	112	528
5	S	8	R	96	4	20	0	0	28	36	0	0	0	0	184
5	S	9	D	64	16	32	0	0	176	48	0	0	0	112	448
5	S	9	R	24	0	152	0	0	4	16	0	0	0	8	204
6	GW	1	D	0	5	145	6	0	171	120	13	1	0	0	462
6	GW	1	R	0	13	133	0	0	120	46	2	2	0	0	346
6	GW	2	D	0	8	76	0	4	48	92	20	4	0	160	416
6	GW	2	R	4	8	48	0	4	56	160	40	8	0	28	356
6	GW	3	D	48	0	48	0	0	224	256	0	0	16	288	880
6	GW	3	R	0	116	48	4	0	256	1960	0	0	76	40	2500
6	GW	4	D	78	130	132	2	52	2236	520	52	0	0	312	3514
6	GW	4	R	32	64	20	0	0	312	184	8	0	0	40	660

Sample	Site	Pool	Habitat	Cir	Iso	Amp	Mys	Dec	Cop	Aca	Pol	Ter	Lar	Egg	Total**
6	GW	5	D	0	0	689	0	0	26624	768	0	0	64	1536	29681
6	GW	5	R	12	20	77	0	0	4984	60	0	0	44	45	5242
6	GW	6	D	0	0	0	0	0	0	256	0	0	64	384	704
6	GW	6	R	48	16	16	198	0	16	0	0	0	0	80	374
6	GW	7	D	544	96	192	16	0	4048	1184	0	0	64	5136	11280
6	GW	7	R	40	23	25	1	0	192	132	0	4	0	100	517
6	GW	8	D	192	0	0	0	0	80	112	32	17	0	48	481
6	GW	8	R	352	12	9	0	0	40	56	0	21	0	4	494
6	GW	9	D	704	832	715	256	0	768	192	0	0	0	448	3915
6	GW	9	R	16	2188	1060	56	0	120	64	0	0	0	4	3508
6	Q	1	D	48	4	0	0	0	92	116	0	0	16	4	280
6	Q	1	R	32	0	4	0	0	4	108	4	0	16	0	168
6	Q	2	D	140	4	4	0	0	252	76	0	0	40	128	644
6	Q	2	R	8	0	0	0	0	54	10	1	0	17	4	94
6	Q	3	D	20	0	66	0	0	228	184	56	0	36	84	674
6	Q	3	R	0	1	2	0	0	12	25	0	0	2	0	42
6	Q	4	D	80	8	10	0	0	552	352	8	4	60	64	1138
6	Q	4	R	0	4	4	0	0	140	208	0	0	32	0	392
6	Q	5	D	28	16	24	0	0	408	200	20	4	20	16	736
6	Q	5	R	0	0	0	0	0	20	92	0	0	68	0	180
6	Q	6	D	0	4	24	0	1	72	100	0	4	12	12	229
6	Q	6	R	4	4	12	0	0	28	132	0	0	28	0	208
6	Q	7	D	4	8	4	0	0	36	104	4	8	52	8	232
6	Q	7	R	1	3	1	0	0	11	9	0	4	16	1	46
6	Q	8	D	0	0	211	0	0	704	160	2	0	64	80	1221
6	Q	8	R	0	0	56	0	0	80	52	8	0	36	0	232
6	Q	9	D	16	0	60	0	0	240	144	0	0	48	320	848
6	Q	9	R	0	4	0	0	0	26	29	1	0	2	2	64
6	S	1	D	64	4	54	0	0	320	128	1	0	4	16	591
6	S	1	R	12	0	44	0	0	16	72	0	0	0	0	144
6	S	2	D	104	0	10	0	0	356	12	8	0	4	3024	3518
6	S	2	R	40	15	18	0	0	88	12	0	4	4	156	337
6	S	3	D	4	8	13	0	0	28	56	4	0	4	16	133
6	S	3	R	40	65	52	0	1	52	68	0	0	4	20	302
6	S	4	D	100	72	90	0	8	300	64	0	0	4	256	894
6	S	4	R	5	1	8	0	0	2	18	0	0	0	2	36

Sample	Site	Pool	Habitat	Cir	Iso	Amp	Mys	Dec	Cop	Aca	Pol	Ter	Lar	Egg	Total**
6	S	5	D	12	0	92	0	4	540	112	0	0	0	124	884
6	S	5	R	4	3	43	0	0	96	240	0	0	4	12	402
6	S	6	D	28	8	12	0	0	628	148	0	0	12	240	1080
6	S	6	R	3	2	2	0	0	63	24	0	0	1	1	96
6	S	7	D	44	1	150	0	0	32	32	0	0	4	52	315
6	S	7	R	24	0	104	0	0	16	16	0	0	0	0	160
6	S	8	D	60	0	42	0	0	616	56	0	0	4	140	926
6	S	8	R	16	5	7	0	0	36	36	0	0	8	12	120
6	S	9	D	512	16	496	0	0	736	112	17	0	16	272	2177
6	S	9	R	180	8	32	0	0	24	96	0	0	4	12	356
7	GW	1	D	16	4	44	0	0	64	108	0	0	4	20	260
7	GW	1	R	0	0	24	0	0	28	56	0	0	0	4	112
7	GW	2	D	64	32	64	0	0	128	176	0	0	0	320	784
7	GW	2	R	4	0	8	0	0	0	88	0	0	0	0	100
7	GW	3	D	64	48	208	0	0	864	1024	0	0	0	240	2448
7	GW	3	R	0	128	24	0	4	96	756	0	0	16	0	1024
7	GW	4	D	48	176	80	0	0	384	176	192	0	0	80	1136
7	GW	4	R	16	136	40	0	0	148	244	0	0	4	8	596
7	GW	5	D	64	0	640	0	0	448	0	0	0	0	1436	2588
7	GW	5	R	20	40	32	0	0	52	220	0	0	0	0	364
7	GW	6	D	0	0	0	256	0	1536	1536	0	256	0	512	4096
7	GW	6	R	20	28	0	0	4	20	32	0	0	8	12	124
7	GW	7	D	92	92	56	0	4	216	188	4	4	4	300	960
7	GW	7	R	0	12	20	4	4	24	16	0	0	0	0	80
7	GW	8	D	52	72	12	0	0	44	168	4	0	0	8	360
7	GW	8	R	0	28	4	0	0	12	48	0	0	4	0	96
7	GW	9	D	64	320	512	0	0	256	0	0	0	0	128	1280
7	GW	9	R	16	2096	688	0	0	48	80	0	0	0	0	2928
7	Q	1	D	4	0	4	0	0	24	36	4	0	0	0	72
7	Q	1	R	8	4	0	0	0	8	120	4	0	0	0	144
7	Q	2	D	80	16	0	0	0	240	128	0	0	96	96	656
7	Q	2	R	8	0	0	0	0	24	4	0	0	12	0	48
7	Q	3	D	16	16	0	0	0	208	192	0	0	48	64	544
7	Q	3	R	0	0	0	0	0	28	88	0	0	28	0	144
7	Q	4	D	128	0	16	0	0	304	112	0	0	144	80	784
7	Q	4	R	20	16	0	0	0	196	228	0	0	16	20	496

Sample	Site	Pool	Habitat	Cir	Iso	Amp	Mys	Dec	Cop	Aca	Pol	Ter	Lar	Egg	Total**
7	Q	5	D	64	16	16	0	0	384	64	32	0	32	48	656
7	Q	5	R	8	12	12	0	0	136	248	0	0	8	0	424
7	Q	6	D	12	0	64	0	0	66	96	0	0	8	4	250
7	Q	6	R	0	4	32	0	0	16	32	0	0	8	0	92
7	Q	7	D	8	0	20	0	0	204	96	16	0	4	0	348
7	Q	7	R	0	0	0	0	0	12	24	0	12	0	0	48
7	Q	8	D	0	16	80	0	0	816	160	0	0	32	80	1184
7	Q	8	R	0	4	8	0	0	44	52	0	0	8	0	116
7	Q	9	D	8	0	24	0	0	76	36	16	0	0	0	160
7	Q	9	R	0	0	4	0	0	0	120	0	0	0	8	152
7	S	1	D	64	16	112	0	0	112	32	0	0	0	80	416
7	S	1	R	0	0	108	0	0	4	0	0	0	0	0	172
7	S	2	D	16	0	8	0	4	120	8	0	0	0	20	176
7	S	2	R	12	0	12	0	4	40	20	0	0	4	0	104
7	S	3	D	496	176	80	0	0	192	48	0	0	0	80	1072
7	S	3	R	60	60	56	0	0	48	80	0	0	0	0	304
7	S	4	D	20	8	4	0	0	16	52	4	0	0	12	116
7	S	4	R	12	4	20	0	0	28	40	0	0	0	0	104
7	S	5	D	80	32	128	0	0	464	288	0	0	16	48	1056
7	S	5	R	16	0	100	0	0	132	176	0	0	0	0	424
7	S	6	D	20	4	0	0	0	228	68	0	0	0	40	360
7	S	6	R	16	0	0	0	0	80	36	0	0	4	12	148
7	S	7	D	176	0	352	0	0	560	176	0	0	16	48	1328
7	S	7	R	16	12	104	0	0	208	376	0	0	4	0	720
7	S	8	D	0	8	4	0	4	108	64	0	0	0	12	200
7	S	8	R	8	0	20	8	8	4	24	0	0	0	0	80
7	S	9	D	0	4	92	0	0	24	40	0	0	0	0	160
7	S	9	R	4	0	112	0	0	12	24	0	0	0	0	152

****Abbreviations are as follows: Cir = Cirrapedia, Iso= Isopoda , Amp = Amphipoda, Mys = Mysidacea, Dec = Decapoda, Cop = Copepoda, Aca = Acarina, Pol = Polychaeta, Ter = Terrestrial invertebrates, Lar = Larvae of the species *Cunio***

BIOGRAPHY OF THE AUTHOR

Amy Marie Gullo was born in Rochester, New York, on February 14^{th}, 1978. She graduated with honors from Fairport High School in 1996. She attended Pennsylvania State University from 1996-1998, and transferred into the Biology program at Binghamton University. She graduated summa cum laude in December of 1999, receiving a B.S. in Biology. She entered the Ecology and Environmental Sciences graduate program at The University of Maine in the fall of 2000, and later changed majors to Zoology. Amy is a candidate for the Master of Science degree in Zoology from The University of Maine August, 2002.