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Resident Benthic Fishes of Artificial Reefs in the Mississippi Sound: Effects of Habitat Relief and Subregion

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The University of Southern Mississippi

RESIDENT BENTHIC FISHES OF ARTIFICIAL REEFS IN THE MISSISSIPPI SOUND: EFFECTS OF HABITAT RELIEF AND SUBREGION

by

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ABSTRACT

RESIDENT BENTHIC FISHES OF ARTIFICIAL REEFS IN THE MISSISSIPPI SOUND: EFFECTS OF HABITAT RELIEF AND SUBREGION

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One of the fundamental questions of artificial reef research concerns the capability of these manmade structures to promote secondary production. Many researchers have questioned whether artificial reefs increase the production of fish biomass, or simply aggregate existing fish biomass. Most previous research has focused on production of transient fish biomass, because of the high recreational and commercial value of these species. Establishing a link between transient fish production and artificial reef primary and secondary production has proved difficult. Therefore, the goal of this study was to examine the productivity of benthic fishes resident to artificial reefs in the Mississippi Sound, and to link this productivity to the artificial reef community through trophic relationships. This study examined differences in condition of benthic fishes resident to four artificial reefs of two profile types distributed across the Mississippi Sound. Poorer condition was found in several benthic fish species on concrete high profile reefs relative to low profile oyster shell reefs. Subregion also appeared to effect poorer condition in the eastern subregion. Diet volume was low in *Gobiesox strumosus* from high profile reefs, and contents differed across both reef types and subregions. Differences in diet contents may have been related to prey taxa tolerance of abiotic conditions and substrate type preferences. These results suggest reef material, design and abiotic conditions relating to specific reef location may affect availability or accessibility to specific prey taxa for resident fishes, and that this may in turn strongly affect production of biomass in resident fishes.

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TABLE OF CONTENTS

LIST OF TABLES

Table

LIST OF ILLUSTRATIONS

Figure

CHAPTER I

INTRODUCTION

Background

Artificial structures have been used for centuries as a means of attracting fish to a location where they may be more easily exploited by man (Sato 1985). Modern artificial reef projects have been widely justified as a strategy to increase the production of commercially or recreationally desirable fish species (Bohnsack and Sutherland 1985; Nakumara 1985; Santos and Montiero 1998). Yet, the question of whether artificial reef structures increase the capacity of fish biomass production is still a matter of serious scientific debate (Baine 2001; Bortone 1998; Brickhill et al. 2005; Grossman et al. 1997; Pickering and Whitmarsh 1997; Powers et al. 2003). Artificial reef construction continues to be a widespread practice despite this lack of a consensus about fish biomass production. The possible adverse effects of reef construction; the aggregation of already over exploited fish stocks leading to exposure to increased fishing pressure, and the loss of other potentially valuable habitat with conversion to reef construction sites (Polovina 1989) have also prompted further investigation into the production verses aggregation question.

Despite the controversy surrounding artificial reefs there is a need to increase fisheries production to support increasing demand and to mitigate damage already done to fish stocks and habitat. Construction of artificial reef habitat is often proposed as a means to achieve such aims. Artificial reefs may provide important habitat for sessile benthic invertebrates which require hard substrate for settlement and growth, especially where availability of natural hard substrata is limiting. Some of these sessile organisms in the northern Gulf of Mexico (GoM), include the eastern oyster (*Crassostrea virginica*) several barnacle species (*Amphibalanus improvisus*, *Amphibalanus eburneus,* and *Amphibalanus amphitrite),* and mussel species (*Brachidontes exustus*, *Ischadium recurvum*, *Brachidontes domingensis*). These species not only provide structure for sessile organisms and thus food for motile reef residents, but also refuge from predators (Soniat et al. 2004; Tolley and Volety 2005), and breeding substrate (Crabtree and Middaugh 1982). Thus, with their growth they contribute additional hard substrate habitat (Meyer and Townsend 2000) and vertical structure (Soniat et al. 2004). For these reasons oysters, stony corals and other sessile reef-building species are often referred to as ecosystem engineers (Gutiérrez et al. 2003; Jones et al. 1994). As such, where artificial reefs have been successfully colonized by ecosystem engineer species, the reef may over time converge to become more similar to naturally occurring reefs (Luckenbach et al. 2005; Meyer and Townsend 2000; Thanner et al. 2006) in terms of the benthic community, and thus have the potential to mitigate for natural habitat loss.

Artificial Reefs as a Proxy for Natural Oyster Reefs

Oyster reefs have long been considered important, largely for their potential to enhance fishery exploitation (oyster and finfish), yet there is also increasing recognition of the many other important ecosystem functions they serve (Beck et al. 2011). These include provision of hard bottom habitat to many ecologically important benthic invertebrates (Lenihan et al. 2001; Rodney and Paytner 2006) and demersal fishes (Coen et al. 1999; Lenihan et al. 2001), refuge from predators (Shervette et al. 2004; Soniat et al. 2004), foraging substrate (Coen et al. 1999; Lenihan et al. 2001), protection of resident species from environmental stressors such as hypoxia (Lenihan et al. 2001; Lenihan and Peterson, 1998), reduction of shoreline erosion (Stricklin et al. 2010) and may have a positive effect upon water quality through filtration (Coen et al. 2007; Newell et al. 2007; Pomeroy et al. 2006). There has been a significant investment in the construction of artificial oyster reefs in recent years, often to replace degraded natural reefs, or to mimic their functions in areas where there is little natural hard substrate.

Oyster Reef Functions

Oyster reefs provide habitat to a wide variety of fish species. Breitburg (1999) categorized oyster reef fishes into three groups: transient fishes, facultative residents, and resident species. Transient fishes were characterized as species that while often quite abundant on reefs are wide ranging as adults, Spot (*Leiostomus xanthurus*) and Pinfish (*Lagodon rhomboides*), for example. Facultative residents are those that are not generally wide ranging, but are found utilizing a wide variety of structured habitats other than oyster reefs, e.g. Black Sea Bass (*Centropristis striata*). Residents are those species that are primarily found on oyster reefs and that may depend upon them for at least part of their life cycle, such as the Naked Goby (*Gobiosoma bosc*), the Oyster Toadfish (*Opsanus tau*), and various blennies. These resident fishes are benthic inhabitants of nearshore structured habitats.

Artificial reef habitat, like natural reef, has the potential to promote production of recreationally and commercially important transient fish species. Under circumstances where there is a bottleneck in production caused by the limited availability of hard substrate either to the target species itself or to any level of the biotic community which trophically supports the target species, addition of artificial reef material has the potential to increase production. Sport fish species commonly targeted in the Mississippi Sound, such as Spotted Seatrout (*Cynoscion nebulosus*) and Red Drum (*Sciaenops ocellatus*) are considered to be transient fishes as classified by Breitburg (1999), and are therefore not dependent on hard substrate directly to complete their life cycle. In visiting artificial reefs however they may benefit from food sources, such as resident reef fishes and invertebrates (Boothby and Avault 1971; Darnell 1961; Hettler 1989; Overstreet and Heard 1978; Overstreet and Heard 1982) which are dependent on reef structure. Reefs may be important for providing greater food availability, or a higher quality of food relative to other available habitat types (Harding and Mann 2001b). Thus, artificial reefs may offer higher trophic transfer potential to sport fishes than the background substrate on which reef material is deployed. For example, Harding and Mann (2001a) showed Bluefish (*Pomatomus saltatrix*) feeding in areas with oyster shell substrate consumed more teleosts than similar fish feeding on sandy substrate. Artificial reef structure which promotes production of benthic invertebrates and resident benthic fishes may therefore have some benefit to sport fish species production.

The hard substrate provided by oyster reefs provides a basis for production of structural complexity for a community of residents through shell growth, community diversity by producing and maintaining habitat suitable for other reef residents, and benthic secondary production through benthic pelagic coupling. Oysters and other filter feeders remove organic material from the water column, increasing their own biomass as well as producing faeces and pseudofaeces, a process which directs energy to the benthic pathways (Peterson et al. 2003).. This organic material provides an additional food source to deposit feeders and grazing invertebrates (Dame and Patten 1981, Harding and Mann 2001a). Furthermore this production benefits carnivorous predators like mud crabs that feed on young oysters (Dame and Patten 1981), and resident fishes that feed on a wide variety of benthic invertebrates (Breitburg 1999) present on oyster reefs. Stimulation of secondary production through organic deposition, production of mollusk biomass as well as the provision of complex structure all potentially increase resident fish and invertebrate productivity on reefs.

Aside from providing a rich food source oyster reefs provide a host of other benefits to motile reef residents, firstly by providing structural habitat. The complex three dimensional structure provided by oysters and other associated sessile organisms provide refuge from predators to many fishes and motile invertebrates, which may in of itself limit production (Grabowski 2004; Hixon 1998; Shervette et al., 2004). Complexity of the habitat may also reduce the efficiency of predators (Grabowski and Kimbro 2005) allowing an increase in prey density relative to less complex habitats (Crowder and Cooper 1982). Complex habitats may reduce interference between conspecifics and intermediate predators, therefore allowing higher predator densities than would be found in less complex habitats (Grabowski and Powers 2004). Overall, increasingly complex habitats tend to support greater species richness and density of organisms (Diehl 1992), although survival benefits vary by trophic level (Grabowski and Powers 2004).

Oyster reef substrate in of itself may have specific benefits to resident reef fishes. While capable of surviving outside of oyster reef habitat, resident reef fishes clearly favor this substrate over soft bottom habitats. As Plunket and La Peyre (2005) showed, although benthic oyster reef resident fishes may occur on soft bottom habitat, they can be more than twice as abundant on oyster reef. Resident fishes may benefit from oyster reefs in a variety of ways. As with transient species, additional hard substrate may provide more or better quality food. For example, Tolley and Volety (2005) noted in their study that the Gulf Toadfish (*Opsanus beta*), was only found in oyster shell habitats where the mud crab (*Eurypanopeus depressus*) was also present. As the Gulf Toadfish is known to consume xanthid crabs, this suggests they seek out this habitat in pursuit of food rather than, or in addition to, the structure itself.

For other species of benthic fishes however, intact articulated oyster shells, known as oyster boxes, may be extremely important structures. Tolley and Volety (2005) also demonstrated higher organism density, biomass and species richness in relation to shell substrates verses sand. This, in the case of some benthic fishes (e.g. the Frillfin Goby, *Bathygobius soporator*), was related to articulated dead shell rather than live oysters, although recent work suggests live oysters also provide other unique habitat features for benthic resident fishes (Beck and La Peyre 2011). The former authors attributed their observations to the use of oyster boxes as breeding substrate, behavior that Crabtree and Middaugh (1982) showed to be highly selective and common to several species of benthic fishes found on oyster reefs. Therefore, oyster shell may also be considered important as breeding habitat to many resident fish species.

Artificial Reef Implementation

In the United States, artificial reef construction is a widespread practice carried out by organizations from the level of the State down to local fisherman's associations (Grossman et al. 1997); however, these programs are often uncoordinated with any specific fisheries management plan. As a result, reefs are often deployed with only the broad aim of fisheries enhancement, and no well defined objectives to be met (Bortone 2011), it is therefore difficult to assess their success or failure in terms of actual resource enhancement. Despite this, there is significant state government spending on the creation of artificial reef structures (Grossman et al. 1997) promoted by the National Fishing Enhancement Act, 33 U.S.C. secs. 2101-2105 (1984) (Murray 1994).

Artificial Reef Materials and Design

Artificial reef construction varies significantly with the specific objectives, budget, and location of the project. Materials used in artificial reef construction range from purpose built units, which are designed to act as habitat for specific species (Grove et al. 1989; Spanier 1994) to material that is simply intended to act as a structure to aggregate fish. Reef projects with very broad aims, such as fish aggregation for recreational fishing or diving, often utilize scrap material including tires (Collins et al. 2002), derelict vessels (Fowler and Booth 2012a), concrete culverts (Brock and Norris 1989), and stabilized coal waste (Woodhead et al. 1982) as artificial substrate. Use of these so called materials of opportunity is often much cheaper than the use of built for purpose units, however there may be other draw backs. Some waste materials, such as car bodies, may be insufficiently long lasting in a marine environment. Sheppard (1974), for example, noted car bodies used as artificial reefs in Texas waters were lost within three to five years of deployment. Some materials may also provide less suitable habitat for specific species; metal and scrap tires, both frequently used in reef construction, have been shown to be less suitable as substrate for a variety of hard and soft corals (Fitzhardinge and Bailey-Brock 1989) relative to concrete surfaces. Sessile species in particular have been shown to have very specific microhabitat preferences (Buschbaum 2001; Crisp and Barnes 1954; Tamburri et al. 2008), which may mediate colonization of invertebrates to artificial reef surfaces. Microhabitat may also influence post colonization survival. For example, Nestlerode et al. (2007) noted reduced growth and survival of young oysters colonizing artificial surf clam shell reefs compared to oyster shell cultch. It was hypothesized that surf clam shell offered less structural complexity than oyster cultch and thus more limited refuge potential for young oysters from predators such as mud crabs. In cases where materials of opportunity are employed in artificial reef construction it is apparent that suitability of the material to the aims of the project must be considered. If a reef construction project aims to promote production of biomass of a target fish species for example, selection of material should consider not just the suitability to the target fish species but also to related predator and prey species.

Beyond the base materials used there is a huge variety in the structural design of artificial reefs, which range from simple concrete blocks (Hixon and Beets 1989) to complex molded concrete modules (Brock and Norris 1989; Charbonnel 2002; Jordan et al. 2005; Sherman et al. 2002; Sonu and Grove 1985). Structural complexity is well understood to be an important property of natural habitats promoting species richness and diversity (Grabowski and Powers 2004; Lenihan and Peterson 1998; Summerson and Peterson 1984). Complexity should therefore also be an important consideration when selecting materials and reef design appropriate to any specific goals for constructing an artificial reef. A number of studies have noted that the variety of construction designs in reef structure produce varying results for different species. For example, finfish in general have been shown to prefer cylinders with multiple entrances, although preferences may be more specific, with rockfish (Sebastidae), for example, showing a preference for dice shaped blocks (Pickering and Whitmarsh 1997). Structural properties including reef size (Ambrose and Swarbrick 1989; Bohnsack et al. 1994), vertical relief (Anderson et al. 1989; Pickering and Whitmarsh 1997), block size (Pickering and

Whitmarsh 1997), structural complexity (Sherman et al. 2002; Willis and Anderson 2003) and refuge size (Kellison and Sedbury 1998) have all been shown to produce differences in reef communities. These various aspects of reef construction affect species and their life stages differently and may alter the way in which species interact. For example, Hixon and Beets (1989) showed creating reefs with many large cavities resulted in an increased abundance of large piscivorous fishes, which in turn limited the small fish population due to increased predation pressure.

Reef Size and Elevation

In natural oyster reefs, reef elevation has been identified as an important factor affecting reef communities and productivity. For oysters themselves, which as noted previously have a strong influence on the reef community (Dame and Patten 1981; Grabowski and Kimbro 2005; Grabowski and Powers 2004; Harding and Mann 2001a; Harding and Mann 2001b) reef height may significantly impact access to and quality of food (Lenihan 1999). Changes in oyster reef height through over exploitation have also been associated with large scale loss of oysters (Lenihan and Peterson 1998) and resident fish and invertebrates (Lenihan et al. 2001) due to the loss of refuge habitat. Reef relief has also been demonstrated to be an important factor for at least some resident benthic fishes on a microhabitat scale. Breitburg (1991) observed that Naked Goby larvae showed a strong microhabitat preference for low relief areas in proximity to high relief objects, but avoided settlement on the high relief objects themselves. It is therefore reasonable to consider that reef relief may also impact artificial reef resident fishes and invertebrates.

Both reef size (Ambrose and Swarbrick 1989; Bohnsack et al. 1994) and height (Anderson et al. 1989) are considered to be important features in artificial reef construction, particularly in terms of attracting fishes (Pickering and Whitmarsh 1997). Bohnsack et al. (1994) noted, when comparing a single large reef with several smaller reefs of equivalent total area, there was an increase in the number of species and individuals with several smaller reefs, but greater total biomass with fewer, larger and usually transient fish on the single large reef . Reef relief has also been shown to be important in relation to fish density. For example, Anderson et al. (1989) observed a general trend of increasing density of fishes moving toward the highest point of elevation on artificial reefs; although this study only considered non-cryptic fish species.

Ecological Importance of Benthic Reef Fishes

Benthic fishes, including residents Gobiidae, Gobiesocidae, Blenniidae, and Batrachoididae, are common on oyster reefs and can be extremely abundant, usually numerically dominating other fishes present (Harding and Mann 2000; Lehnert and Allen 2002; Rodney and Paynter 2006; Zimmerman et al. 1989). Annual production estimates of these fishes can also be surprisingly high (Peterson et al. 2003), particularly in terms of larval production (Breitburg et al. 1995).

Predation by these dense aggregations of larval benthic fishes has also been shown to affect oyster reef communities. Benthic larval fishes are significant predators on zooplankton (Breitburg 1999) and several species including Naked Gobies, Striped Blennies, and Feather Blennies (*Hypsoblennius hentz)* have been shown to preferentially feed on oyster veligers even at low concentrations (Harding 1999). As adults, small benthic fishes may be significant predators on oyster reef communities, particularly given the high densities in which they have been reported (Harding and Mann 2000; Rodney and Paynter 2006). Toadfishes (*Opsanus beta* and *O. tau)* especially are known to be significant predators, particularly on crabs, including Xanthidae and Portunidae (Abbe and Breitburg 1992; Abeels et al. 2012; Bisker et al.1989), as well as fish, mollusks and other crustaceans (Odum and Heald 1972). *Gobiosoma* spp. have been reported to consume annelids and small crustaceans (Abeels et al. 2012; Breitburg 1999). Skilletfish diets have been variously reported in one study as being dominated by benthic microalgae, annelids, and particulate organic matter (Abeels et al. 2012), and in others as consisting of small crustaceans, including amphipods and isopods (Odum and Heald 1972; Runyan 1961).

In the past benthic reef fishes, including Naked Gobies, have been dismissed as unimportant in the diets of predatory fishes due to their cryptic lifestyle (Dahlberg and Conyers 1979). However, a number of studies have reported cryptic benthic fishes in the diets of piscivorous fishes. Naked Gobies alone has been reported in the diets of Yellow Bass (*Morone mississippiensis*), Atlantic Croaker (*Micropogonias undulatus*), Pinfish (Darnell 1961) Black Drum (*Pogonias cromis*) (Darnell 1958; Gunter 1945; Overstreet and Heard 1982), Bluefish (Harding and Mann 2001a), and Striped Bass (*Morone saxatilis*) (Buckel and McKnown 2002; Harding and Mann 2003). Gray Snapper (*Lutjanus griseus*) and Spotted Seatrout have also been reported to consume small benthic fishes including Gulf Toadfish and gobiidae (Hettler 1989; Odum and Heald 1972; Yeager and Layman 2011). While cryptic fishes may not be significant in diets of transient fishes at all times they may become more important in diets of piscivorous fish when associated with oyster reefs. For example Harding and Mann (2003) compared diets of Striped Bass on oyster reefs verses oyster shell bar and sand bar habitats. Both shell substrate habitats attracted more Striped Bass, and oyster reef bass diets contained fish more frequently than other sites. Blenniidae and Gobiidae species were part of Striped Bass diets at all locations, however the significant increase in numerical abundances of fish in diets of fish from oyster reefs was attributed to an increase in Gobiidae including Naked Gobies.

As larvae, several species of benthic fishes including Naked Gobies, Striped Blennies and Feather Blennies (Breitburg 1999; Harding 1999; Harding and Mann 2000) form aggregations close to the substrate prior to settlement. Breitburg et al. (1995) reported no apparent reduction in predation mortality due to this behavior, as Naked Goby larvae were observed to be regularly targeted as food by juvenile Striped Bass during this phase of development. As it is unlikely that larval Naked Gobies or other small benthic fishes would be easily identifiable in diets, exploitation of this abundant food source may be under reported in diets of juvenile predatory fishes on oyster reefs. Considering both their abundance as larvae (Breitburg et al. 1995; Harding and Mann 2000) and adults (Harding and Mann 2000; Lehnert and Allen 2002; Peterson et al. 2003) and their inclusion in the diets of a variety of predatory fishes, cryptic resident fishes should be considered as a potentially important trophic link between the oyster reef communities in which they feed and the predatory transient fishes which visit oyster reefs.

Artificial Reefs in the Mississippi Sound

Historically, natural oyster reefs in the Mississippi Sound were not considered to be dense or extensive enough to support an extensive fishery. The shucking and canning industry which did exist in Mississippi in the early 1900's was mostly supported by imports of oysters from Louisiana (Moore 1913). The 1911 Bureau of Fisheries survey in Mississippi Sound by Moore (1913) described the 'barren bottoms,' those areas not naturally productive of oysters, to 'vastly exceed' productive oyster reef area. Moore (1913) did report 475 acres (1.92 km^2) of dense to scattered oysters of marketable size, but noted the often poor quality and low ratio of marketable sized oysters to juveniles. Even this relatively early survey did in fact suggest the construction of artificial reefs for oyster culture in order to support a fishery.

It is understood that the current lack of extensive natural hard substrate in the Mississippi Sound may limit the production of not only oysters but also species dependent on such reef habitat (Shervette et al. 2004). This habitat limitation may have a significant impact on species of commercial and recreational value, either directly (Shervette et al. 2004) or indirectly through trophic associations. Addition of artificial reef material in the Mississippi Sound has been ongoing since the 1960's with the aim of increasing the hard structures available to target species, particularly those of commercial or sport value (e.g. Spotted Seatrout, Black Drum). With the National Fishing Enhancement Act, 33 U.S.C. secs. 2101-2105 of 1984, Congress has actively encouraged the participation of the States in this practice (Murray 1994). Consequently, the Mississippi Gulf Fishing Banks, Inc. (MGFB) Artificial Reef Program, under the auspices of the Mississippi Department of Marine Resources (MS DMR), currently maintains 67 inshore, and 15 offshore reefs, in order to support and enhance recreational fishing in the region. These artificial reefs include both high and low profile structures, and are variously constructed from concrete blocks, crushed concrete and limestone rubble, oyster shell, and other shell cultch.

The aim of this thesis project is to examine four selected artificial reefs in the Mississippi Sound in order to assess the degree to which production of resident benthic fishes is dependent on reef structure. Specifically, resident benthic fishes collected from two types of reef, termed high profile and low profile in both the eastern and western ends of the Mississippi Sound will be compared.

Specific Objectives

- Examine seasonal variation in the resident benthic fish community of artificial reefs in the Mississippi Sound by reef type and subregion;
- Compare condition factors of the most abundant cryptic benthic fishes found on the artificial reefs within the Mississippi Sound by reef type and subregion; and
- Examine the diets of the most abundant cryptic fish species by ontogenetic group, and reef type.

Hypotheses

- Ho_1: Condition factor does not vary by reef type or subregion for the most abundant resident fish species found on artificial reefs in the Mississippi Sound.
- Ho_2: The diets of the most abundant species of cryptic fish found on artificial reefs do not vary by reef type, subregion or ontogenetically.

CHAPTER II

MATERIALS AND METHODS

Sampling Locations

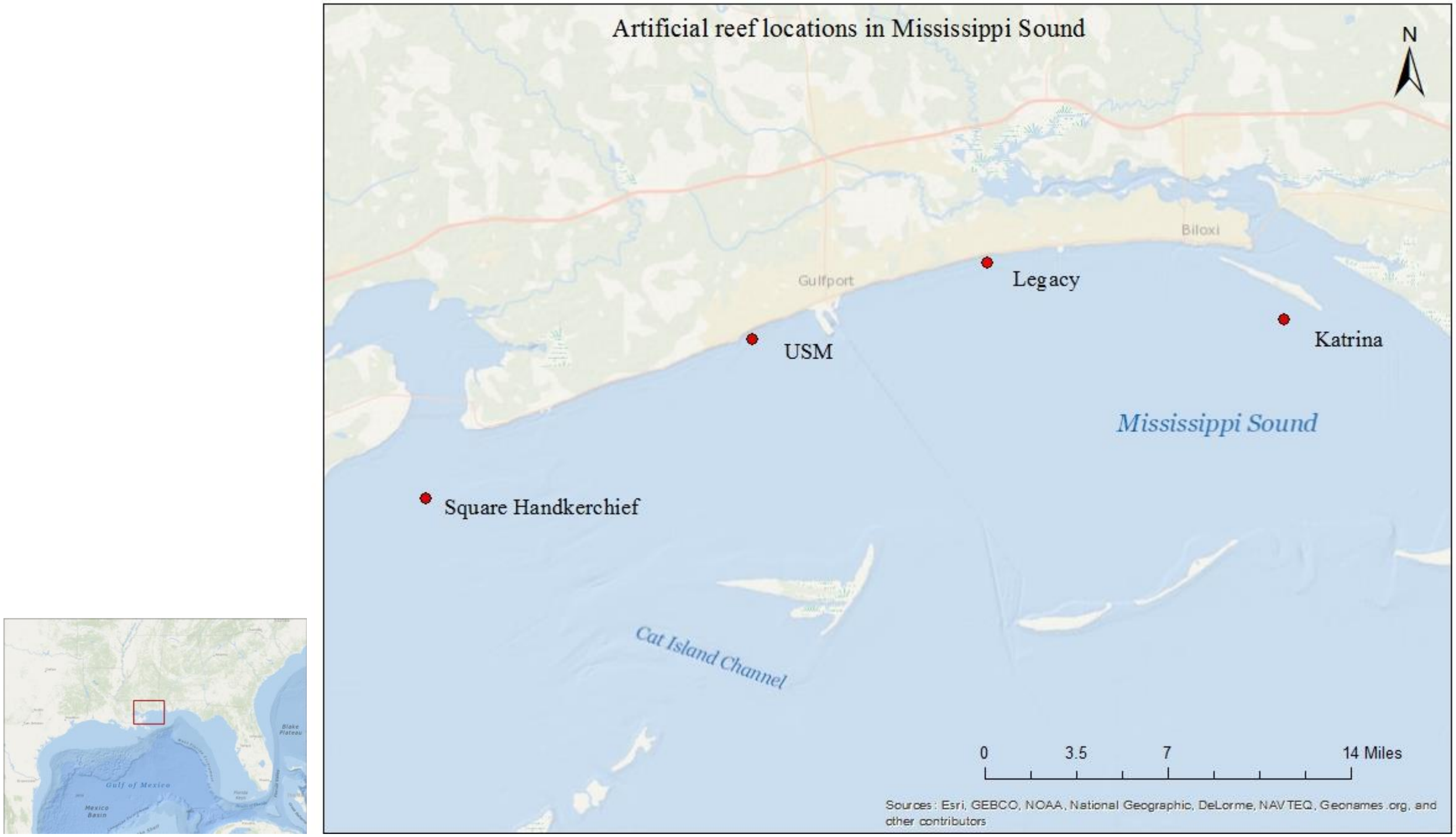
Information on the locations of inshore artificial reefs in the Mississippi Sound was obtained from the Mississippi Department of Marine Resources (MSDMR). This initial list of 55 available sampling locations included two reefs that were termed “high profile” artificial reefs. These high profile artificial reefs were constructed from the remains of bridges destroyed by Hurricane Katrina, including large pieces of concrete rubble and blocks of reinforced concrete which extended beyond the surface of the water at mean high water. Both high profile artificial reefs, henceforth referred to as “Katrina” and “Square Handkerchief” reefs (Figure 1) were selected for this study. The remaining 53 artificial reefs were all classified as “low profile” reefs, as they were completely submerged at mean low water. Low profile artificial reefs were constructed from oyster shell and crushed Limestone. From the list of available low profile artificial reefs a shortlist of five were selected for further consideration as potential study sites. Reef material once deposited naturally settles and subsides into the background sediment over time. Thus, artificial reef material is periodically replenished by the MSDMR. As a result, not all potential sites were suitable for sampling at any one time. To assess the suitability of the shortlisted artificial reefs, mapping of the footprints of these potential sample sites and the available high profile reefs was carried out during the winter of 2010 to 2011.

Artificial Reef Mapping

Mapping of the artificial reef footprints was carried out on five low profile reef locations and the two high profile reef locations. Reef location information supplied by MSDMR gave the maximum possible extent of the reef footprint, termed the “reef box” however, the actual location and extent of the reef within this given area was unknown. In order to map the reef extent at low profile reefs, boat transects were made about 20 meters apart over the entire area of the reef box. Along each transect, at about 20 meter intervals, the bottom substrate was assessed using a PVC pipe. At each location, the bottom substrate was classified as mud/sand, fine material (gravel), coarse material (oyster shell), or solid (reef), and GPS location data were recorded. For the high profile reef locations, boat transects were not carried out over the entire reef box as the visible extent of the artificial reef was a more reasonable starting point. Using a PVC pole, the bottom substrate was felt moving away from the visible extent of the reef until the edge of the reef material was found. The GPS locations for the outer edge of the reef material were recorded at about 20 meter intervals around the periphery of the visible extent of the high profile artificial reefs. The data collected at all locations was plotted using ArcGIS (ver. 9.3) to generate maps of the estimated total footprint area of each potential study site. The estimated area of the low profile reefs was obtained by interpolation of a raster image using the natural neighbor tool in ArcGIS. This method estimates values at points on the raster grid for which values are not available based on weighted proximity to sampled data points for which a value is known. From this interpolated raster map, the total area of each surveyed reef was estimated. Low profile artificial reefs with the greatest estimated total area concentrated in a single block were considered the most suitable for sampling, as these were the easiest locations for proper placement of sampling gear on the reef surface. One low profile reef was selected from the western end of the Mississippi Sound, which will be referred to as “USM” reef, and one in the eastern Mississippi Sound known as “Legacy” reef (Figure 1).

Reef Types

Two distinct reef types were examined during this study: high profile reefs (n=2) constructed from concrete blocks and rubble; and low profile reefs (n=2) made up of a mixture of oyster shell and limestone gravel. My assumption is that the structural habitat formed from these two materials differs due to the relative sizes and regularity of shapes of the constituent objects. High profile reefs are constructed from very large (> 3m), regularly shaped, but haphazardly stacked concrete pilings and large pieces of broken concrete. This material creates large interstitial spaces within the structure of the high profile reefs. Low profile reefs, however, are constructed from very much smaller material, crushed limestone, approximately 2.5cm in diameter, and oyster shell. Low profile reef material settles into a more closely packed structure than the large block material of high profile reefs, and thus creates a greater number of smaller interstitial spaces within the reef structure. These small interstitial spaces may provide appropriately scaled refuge habitat for resident fishes and invertebrates (Hixon and Beets 1989). Interstitial spaces provide refuge for residents from predators (Hixon and Beets 1993; Soniat et al. 2004; Tolley and Volety 2005), as well as spaces for resource partitioning (Grabowski 2004; Meyer 1994; Tolley and Volety 2005) and for breeding (Crabtree and Middaugh 1982).



Sources: Esri, GEBCO, NOAA, National Geographic, DeLorme, NAVTEQ, Geonames.org, and other contributors

Figure 1. Study sites in the Mississippi Sound. Two low profile reefs were selected: “USM” in the western sound and “Legacy” in the eastern sound. Two high profile reefs were selected in Mississippi Sound: “Square Handkerchief” in the western sound and “Katrina” in the east.

Sampling Methods

Sampling Substrate

Sampling of the artificial reefs was carried out using artificial substrate baskets and modified minnow traps filled with oyster shell cultch or crushed concrete. These samplers provided artificial habitat for fishes and both motile and encrusting invertebrates commonly resident on natural oyster reefs and artificial reefs in the Mississippi Sound. Concrete substrate material was obtained from MSDMR. Oyster shell cultch was obtained from a commercial oyster waste dump area.

Sampling Gear

Two different sets of samplers were used to collect benthic organisms during this study. For the collection of both benthic invertebrates and fishes for diet analysis, cylindrical substrate baskets measuring 17.2 cm (diameter) x 27.7cm (length) with a 23.4 mm mesh were filled with either clean oyster shell cultch or crushed concrete. The large mesh of the substrate baskets allowed free movement of any fish between the basket and the reef surface to feed. This ensured movement of any fish collected using the substrate baskets was not restricted in a way which might have altered the fish diets. Each basket rig consisted of two substrate baskets, one containing each substrate type, shackled to a line two meters apart. The line was weighted at both ends, half a meter from the end of each basket, and connected to a surface buoy on one end. Substrate basket samplers were set at four locations on each of the four artificial reefs, for a total of 32 baskets set at 16 locations and allowed to soak for approximately six weeks during April and May 2012 before being recovered. Basket rigs were recovered *in situ* by snorkeling to each basket and placing each one into a 1mm mesh bag which was cinched closely around the attached line before retrieving the entire sampler to the boat. Each basket was placed directly into a five gallon bucket which was then filled with enough sea water to cover the material, and returned to the lab for further processing.

A second set of samplers consisted of a modified pair of minnow traps to collect cryptic benthic fishes. Each rig included a pair of standard minnow traps (length 40.64 cm x end diameter 16.83 cm x central diameter 21.59 cm) lined with 3.175 mm mesh aquaculture netting (VEXAR). One half of each trap was filled with clean oyster cultch. Initially two traps were attached to each line spaced two meters apart, with two weights attached to the either end of the line on the outside of the traps. This arrangement was found to be impractical in the case of the high profile reefs, as excess line easily wrapped around debris commonly found at the high profile sites. Subsequently, on high profile reefs each trap was set on an individual weighted line, with the trap attached about 25 cm from the weight. From preliminary work, a two week soak time was found to be sufficient to allow colonization of fishes to the cultch material. As the minnow trap samplers were used only for fish collection, and not also for benthic invertebrates, the minnow trap samplers were allowed to soak for two weeks before being recovered. As far as was possible, recovery was conducted on consecutive days, with all samplers recovered and reset on two reefs within the same day. At each sample site, surface and bottom water temperature (ºC), dissolved oxygen (mg/l), salinity (‰) and conductivity (µs) and secchi depth (m) were recorded before sampler recovery. Upon recovery, the traps were placed immediately into individual plastic tubs and the contents were washed from the trap using sea water. All cultch material was removed from the tubs, carefully checked for any attached cryptic fishes, and returned to the trap for redeployment. The water remaining in each tub was then poured through a one mm sieve. All organisms collected were then washed into one gallon zip lock bags using sea water, labeled, put on ice, and returned to the lab for further processing. All traps were reset for a further two weeks to allow subsequent collections. In total two preliminary collections were made during the autumn of 2011, and three collections each were made during the spring and summer of 2012.

Sample Processing

Lab Processing of Substrate Basket Samples

Once the artificial substrate basket samples had been returned to the lab, they were immediately processed. Initially, all substrate material was agitated within the collection bucket to remove any loose motile organisms. The substrate material was then poured into a plastic tub partially filled with 63µm filtered sea water. The empty basket was then washed in the collection bucket to remove any attached organisms. At this point air stones were used to aerate the water to keep any fish or invertebrates alive. Substrate material was individually washed in filtered sea water to remove loose organisms and returned to the transport bucket. Once this process was complete, the filtered sea water was passed through a 0.5 mm sieve to collect any organisms which had been removed from the substrate. Any fish collected were placed in a ziplock bag with seawater and placed on ice until processing was completed. All other material retained in the sieve was then fixed in 10 % formalin. Each individual piece of material was scraped to remove epifaunal organisms, excluding barnacles, and washed into the original bucket water. Subsamples of material were scraped to collect barnacles. Once this process was complete the bucket water was passed through a 0.5 mm sieve to collect any remaining fish and invertebrates. Any remaining fish were separated from the rest of the samples and placed in ziplock bags on ice prior to being fixed in 10% formalin solution. The remaining organisms were then added to the rest of the corresponding sample previously fixed in 10% formalin. In the final stage of processing, the scraped substrate material was placed into a fresh water bath for fifteen minutes to force out any invertebrates from cracks and interstices in the substrate material. Each item of substrate was rinsed in the bath and removed before the fresh water was passed through a 0.5 mm sieve to retrieve any invertebrates, which were also added to the corresponding sample jar and fixed in 10% formalin.

Lab Processing of Minnow Trap Samples

Once the trap samples reached the lab, all collected organisms had been on ice for several hours, in accordance with the use of fishes guidelines published by the American Fisheries Society and American Society of Ichthyologists and Herpetologists (http://fisheries.org/docs/policy_useoffishes.pdf). Recovered organisms were fixed in ten percent formalin solution, and any fish larger than 15 cm were cut to allow formalin to enter the body cavity. All samples were left in formalin solution for several days before they were rinsed and processed further.

Each fish collected was identified to species or the lowest possible taxonomic level, weighed to the nearest 0.001g (blotted wet weight), and measured for Standard Length (SL), Head Length (HL), and Gape Width (GW) each to the closest 0.1 mm. Each fish was then assigned a unique identifying number and tagged. Fishes obtained from modified minnow traps were placed in seventy percent ethanol for storage. Once this process was completed for fishes collected from both types of sampling gears, the most common species across all locations, Skilletfish, was selected for diet analysis. All Skilletfish collected from the substrate baskets were divided into three size classes: SL $\leq$ 30 mm (small size class), SL $>$ 30 and $\leq$ 45 mm (medium size class), and $>$ 45 mm (large size class). For each reef, up to 30 Skilletfish, or as many as were available, were selected from each size class using randomly generated numbers. The entire digestive tract was removed from each fish and the contents processed. All diet items were identified to the lowest possible taxonomic level and the number of items for each type recorded. Any unidentified material in the diet was also retained for volumetric analysis.

Determination of Diet Volumes

The volumes of organisms collected the Skilletfish diets were determined by squashing the sample material between two glass slides which had been calibrated using known volumes of an 80:20 mixture of glycerol and 1% KOH. Once the sample material had been squashed evenly between the calibrated slides a 12 megapixel photograph was taken using a DMX 1200 digital camera mounted on a SMZ 1500 microscope. The outline of the image was then traced using MetaVue (v. 7.1.7) to give the area of the traced image. This process was repeated multiple times until two areas within one decimal place were obtained. These two areas were then averaged to give a reasonable estimate of the squashed area. Using the calibration based on known volumes, the average areas were then converted to estimates of the sample material volume (Hellawell and Abel 1971). In cases where the material was too large to be pressed between the glass slides, blotted wet weight was recorded to the nearest 10^{-4}g using an Ohaus Analytical Plus microbalance. Blotted wet weight was then converted to volume using an assumed density of 1.13g cm^{-3} (Gerlach et al. 1985; Rakocinski 2012).

Statistical Methods

Diet Analysis

Stomach content data were initially examined to determine if a sufficient number of diets had been sampled to give a reasonable representation of the diets of Skilletfish. This was achieved by plotting species accumulation relative to the number of diets sampled using PRIMER (v 5.2.9). As species accumulation varies with the order in which samples are taken, the species accumulation curves were calculated using the average of 999 permutations of a randomized ordering of diets. Resulting plots were then examined to assess whether the number of prey types in the diets was continuing to increase markedly as more samples were added. This process was completed for all samples, and separately by reef to determine if fish diets from each of those were well represented by the samples collected.

Diet taxa richness was also estimated using EstimateS (v 9.1.0) to calculate the expected asymptotic number of prey types in the diet (S(est)) based on extrapolated rarefaction curves for each reef. The estimated asymptotic diet richness, S(est), and the 95% C. I. of S(est) were based on the collected "reference sample" (sensu Colwell et al. 2012). The representation of Skilletfish diets by the collected reference sample was then assessed as a percentage of the calculated S(est).

Log_{10} transformed total dietary volumes for each fish were compared among samples with Analysis of Covariance (ANCOVA) with $\log_{10}$ SL as the covariate. Diet volume ANCOVA comparisons were made by collection reef, reef type, and subregion. Due to the time taken to recover substrate baskets in the field, return baskets to the lab and recover all fish from the sample material feeding periodicity could not be taken into account. Initial comparisons were made to test for violations of the homogeneity of regression slopes assumption by testing for significant interactions between the fixed factor, grouping, and the covariate, $\log_{10}$ fish SL. Where the interaction term was non-significant ($p > 0.05$) the term was removed from the model. The reduced model was then examined for significance of the main effect, the grouping term ($p=0.05$). Pairwise comparisons were made where possible, by comparison of estimated marginal means for which the 0.05 alpha values were corrected using a sequential Bonferroni adjustment (Holm 1979). In cases where there was a significant interaction between the fixed factor, grouping, and the covariate, fish SL, the model could not be reduced and no pairwise comparisions were possible.

Volume data for each prey category was converted to percentages based on the total diet volume for each fish sampled. This information was used to generate an arcsine square root transformed Bray-Curtis similarity index using PRIMER (v 5.2.9) including all fish except those with completely empty stomachs or those which contained only unidentifiable material. The Bray-Curtis index was then used to generate multiple Two-Way Analysis of Similarity (ANOSIM) between *a priori* defined sampling groups; fish size class crossed with reef , size class crossed with reef type, and size class crossed with subregion group. The significance of each ANOSIM was based on 999 permutations of all possible samples using the Bray-Curtis dissimilarities. Where more than two levels of a factor were included in the ANOSIM, pairwise comparisons were also conducted following the global test. The significance of pairwise tests was assessed using an alpha value of 0.05, which was adjusted using the sequential Bonferroni method. Based on the significance of ANOSIM results, further comparisons were made between the reef and size class group diets using Similarity Percentages (SIMPER) in PRIMER (v 5.2.9). SIMPER was used to identify the diet items contributing to similarity within groups and dissimilarity between groups as identified by the Bray-Curtis matrix and ANOSIM analysis.

The degree of overlap in fish diets within the individual reefs and between reef type was also examined using Non-metric Multi-dimentional Scaling (MDS) plots created using PRIMER (v 5.2.9). The MDS plots were based on the arcsine square root transformed Bray-Curtis dissimilarity previously calculated for ANOSIM. MDS plots were used to visually compare each of the *a priori* groups in MDS space; fish size class, individual reef, reef type, and subregion group. Data points which obscured the majority of points in the MDS plots due to scaling were removed from duplicate plots of the remaining data points for clarity. The points which were removed from MDS plots were not removed from any analysis.

Condition Factor Analysis

Comparison of condition factors for the six most abundant species was conducted with Analysis of Covariance (ANCOVA) in PASW (v.17.0.2) by reef, and where appropriate by reef type and subregion. The $\log_{10}$ transformed SL-weight data were examined for equality of variance among groups using Levene's test. Where Levene's test was significant but the ratio of variances was less than three, the heterogeneity of variances was not considered severe enough to invalidate the ANCOVA (Keppel et al. 1992). The SL-weight relationships were then examined for any interaction between the fixed factor and SL. In cases where the interaction term was non-significant at an alpha value of 0.05, this term was removed from the ANCOVA model. For the reef groups any significant effect of the fixed factor without the interaction term was further examined via pairwise comparisons with a sequential Bonferroni adjustment (Holm 1979). The estimated marginal means obtained from each ANCOVA were then plotted using Sigma plot (v.11) for visual comparison. In cases where ANCOVA showed a significant interaction term between reef group and the covariant, SL, further analysis could not be conducted using ANCOVA. Therefore, for species with a significant interaction term, separate regression analyses were conducted for each reef group. Regression slopes were then compared for significant differences between reefs with the GT2 method, Sokal and

Rohlf (1981), at an alpha value of 0.05. Comparisons of regression slopes with 95% confidence intervals were then plotted using Sigma plot (v.11). Projections of the SL-weight relationships of each reef group were also plotted based on the regression coefficients at standard length increments selected as representative of the range observed for that species. Where the GT2 method identified reef groups with significantly different SL-weight relationships, these could be removed from the comparison, allowing ANCOVA with the remaining reefs of similar slopes, and thus comparison of estimated marginal mean weight at SL where no further interaction was found.

CHAPTER III

RESULTS

Temperatures across sample locations were broadly comparable within, and showed a similar increase during the course of 2012 sampling time frame (Figure 2), with bottom water temperatures ranging from 20.5 to 31.8ºC at depths of 0.6m to 2.25m at low profile reefs and 1.6m to 3.1m on high profile reefs.

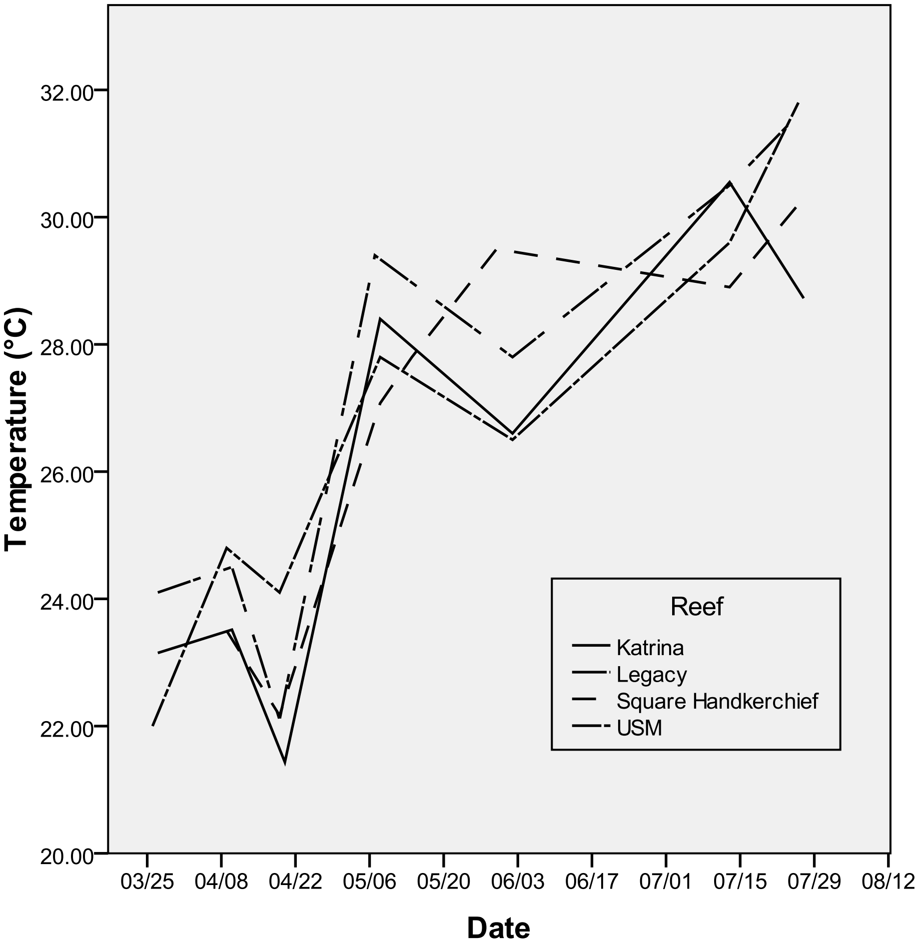


Figure 2. Mean bottom water temperature by reef during 2012 sampling.

Bottom salinity measurements were, however, clearly different when compared across reefs (Figure 3). Bottom salinity ranged from 4.1 at Square Handkerchief reef during April to 30.7 at Katrina reef during July.

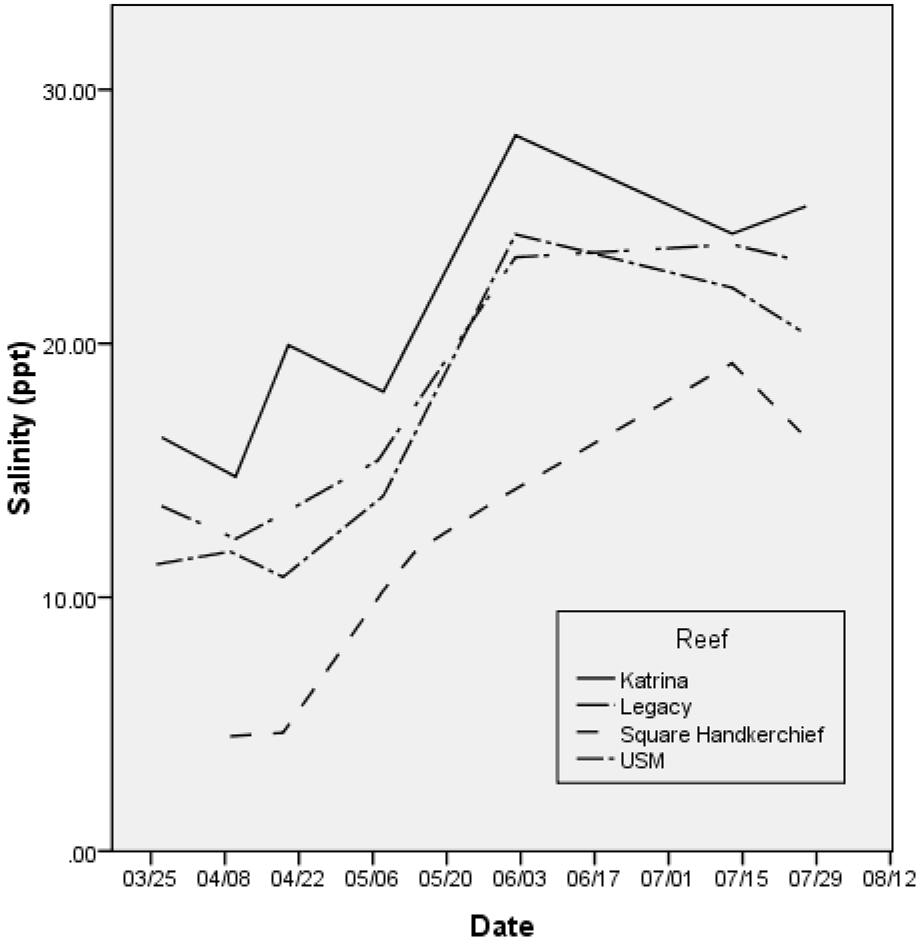


Figure 3. Mean bottom salinity by reef during 2012 sampling.

Comparing sites within similar dates shows generally lower mean salinity at Square Handkerchief reef relative to all other reefs. Katrina reef salinity was generally higher than all other reefs. Bottom salinities at Legacy and USM reefs were similar during the entire sample period and generally intermediate to Square Handkerchief and Katrina reefs. Bottom salinity overall increases from the western most reef, Square Handkerchief, toward the eastern most reef Katrina. Reduced salinity in the western sound can be related to significant fresh water input from Bay St. Louis and the Pearl River. This riverine input to the waters closest to the high profile reefs may also contribute higher turbidity and nutrient load to these areas.

Catch Composition

During the 2012 sampling season, 1,503 fish were collected from modified minnow traps, and 531 fish were collected from benthic sampling baskets for diet analysis. A total of seventeen species were identified from both types of samplers (Table 1); many were rarely collected. Six species were commonly captured in either or both types of samplers; Skilletfish, Naked Goby, Freckled Blenny, Feather Blenny, Featherduster Blenny, and Gulf Toadfish. Catch per unit effort by species was highly variable even between traps within a reef and a season, but some patterns were apparent. The Feather Blenny and Featherduster Blenny were both absent from high profile reefs but present on low profile reefs in meaningful numbers. The Featherduster Blenny was present in substrate basket samples, but poorly represented in concurrent minnow trap samples, suggesting that the type of samplers may have biased the fish collected due to the preferences of different species. The Feather Blenny was also notably absent from both the substrate basket and minnow trap samples during spring sampling, but present in summer samples. The Feather Blenny was the only species which showed a very clearly defined seasonal presence, although Skilletfish also showed some degree of seasonal variation with greater numbers caught during Spring across all reefs. Comparison of fish condition was then conducted by reef, reef type, and subregion for the six most common species.

Table 1

Total Catch Summarized by Season and Capture Method within Each Reef.

	Katrina			**Legacy**			**Square Handkerchief**			**USM**		
Species	Spring (n=9)	Summer (n=17)	Basket (n=8)	Spring (n=13)	Summer (n=22)	Basket (n=8)	Spring (n=13)	Summer (n=18)	Basket (n=8)	Spring (n=19)	Summer (n=24)	Basket (n=8)
Bairdiella chrysoura										1		
Bathygobius soporator		1										
Chaetodipterus faber					1							
Chasmodes bosquianus										3	1	
Diplectrum bivittatum			1									
Gobiesox strumosus	4	1	15	90	9	111	38	21	50	90	31	111
Gobionellus boleosoma	1				1							
Gobiosoma bosc	1	10		9	289		15	67	3	318	117	89
Hypleurochilus caudovittatus (cf)					3						2	
Hypleurochilus multifilis					1	33				5		37
Hypleurochilus sp.				6	1	3				16		2
Hypsoblennius hentz					90						46	
Hypsoblennius ionthas	3	2	3	2	1	4	3	16	15	11	4	16
Hypsoblennius sp.		1									3	

Table 1 (continued).

	Katrina			Legacy			Square Handkerchief			USM		
Species	Spring (n=9)	Summer (n=17)	Basket (n=8)	Spring (n=13)	Summer (n=22)	Basket (n=8)	Spring (n=13)	Summer (n=18)	Basket (n=8)	Spring (n=19)	Summer (n=24)	Basket (n=8)
Lutjanus griseus		1			5						10	
Membras martinica				1								
Myrophis punctatus				1	4						1	
Opsanus beta	17	11	21	7	1	8	6	24	1	10	18	4
Unidentified Sciaenidae	1	2			16			11			9	
Unidentified Blennidae	3			1	1	2					4	

Note. Total catch summarized by season and capture method within each reef. Seasons refer to fish captured using modified minnow traps. Basket column refers to fish captured using substrate baskets during May 2012, concurrent with the Spring column. Number of modified minnow traps or substrate baskets recovered within a season is listed under the respective season or basket columns.

Fish Condition

Fish Condition Comparison by Reef

Condition was compared across samples for the six most abundant species. For the Naked Goby (n = 912), the full ANCOVA model interaction term was non-significant (F_3=1.965, p=0.118), indicating parallel relationships between SL and weight across reefs. The reduced model showed a significant main effect (F_3=3.003, p=0.030) for the Reef factor. Follow-up pairwise comparisons (Table 2) by reef showed a significant difference in Naked Goby condition from Katrina reef relative to all other locations, and no other significant comparisons. Plots of the estimated marginal means (Figure 4) from the ANCOVA indicate a lower weight at length for Naked Gobies at Katrina reef relative to fish of the same size from all other location.

Table 2

Pairwise Comparison of Naked Goby Condition by Reef

(I) Reef	(J) Reef	Sig.	Adj. Alpha
Katrina	Legacy	0.003	0.008
	Square Handkerchief	0.004	0.013
	USM	0.003	0.010
Legacy	Square Handkerchief	0.859	0.017
	USM	0.933	0.050
Square Handkerchief	Katrina	0.004	0.013
	Legacy	0.859	0.017
	USM	0.909	0.025
USM	Katrina	0.003	0.010
	Legacy	0.933	0.050
	Square Handkerchief	0.909	0.025

Note. Pairwise comparison of Naked Goby (*Gobiosoma* bosc) condition based on estimated marginal means of length-weight ANCOVAs. Mean differences are significant at an adjusted alpha level using a sequential Bonferroni adjustment to an alpha value of 0.05

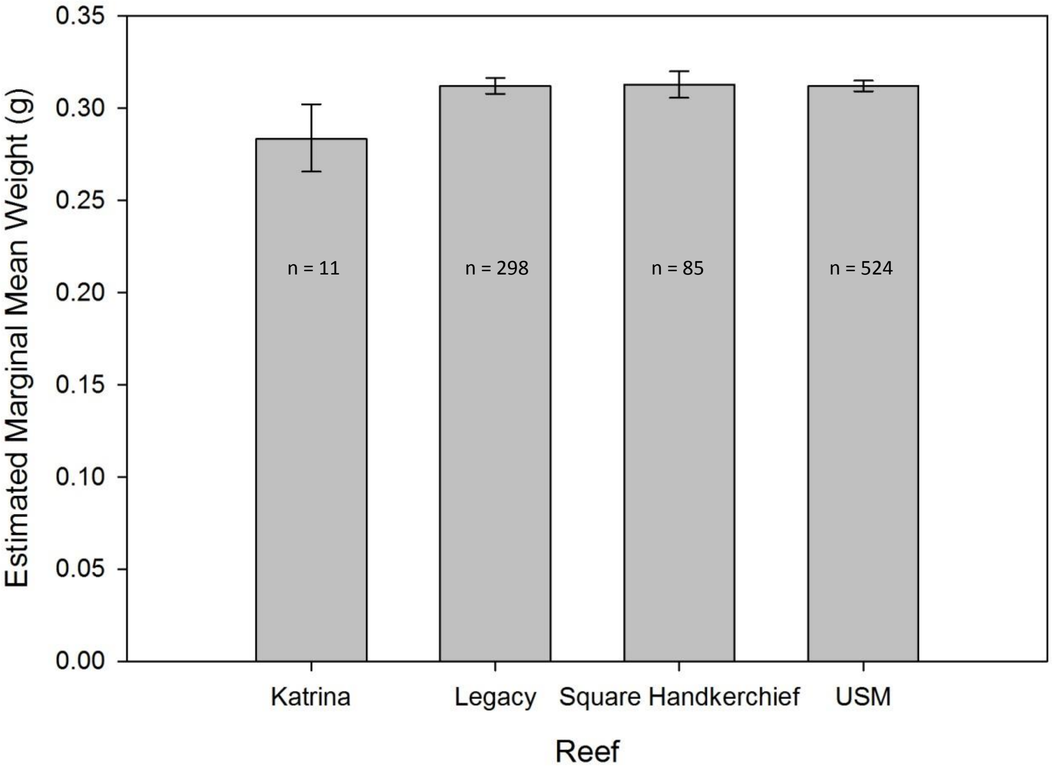


Figure 4. Estimated marginal mean weight (g) of Naked Gobies (*Gobiosoma bosc*) by reef at an adjusted mean standard length of 24.91 mm. Error bars represent ± two S.E. Estimated marginal means based on ANCOVA, where $\log_{10}$ wet weight was the dependent variable and $\log_{10}$ SL was the covariate.

A total of 549 Skilletfish contributed to comparisons of condition among reefs. Significant interaction between the SL and reef factors ($F_3 = 10.398$, $p < 0.001$) indicated different trajectories in the SL-weight relationship. Thus, slopes in the weight at length relationships were not uniform at all reef locations; adjusted means could not be properly compared among reefs using ANCOVA. Skilletfish from USM reef showed a steeper slope in the weight at length relationship relative to fish from other reefs, owing mainly to effects of fish in larger size classes (Figure 5).

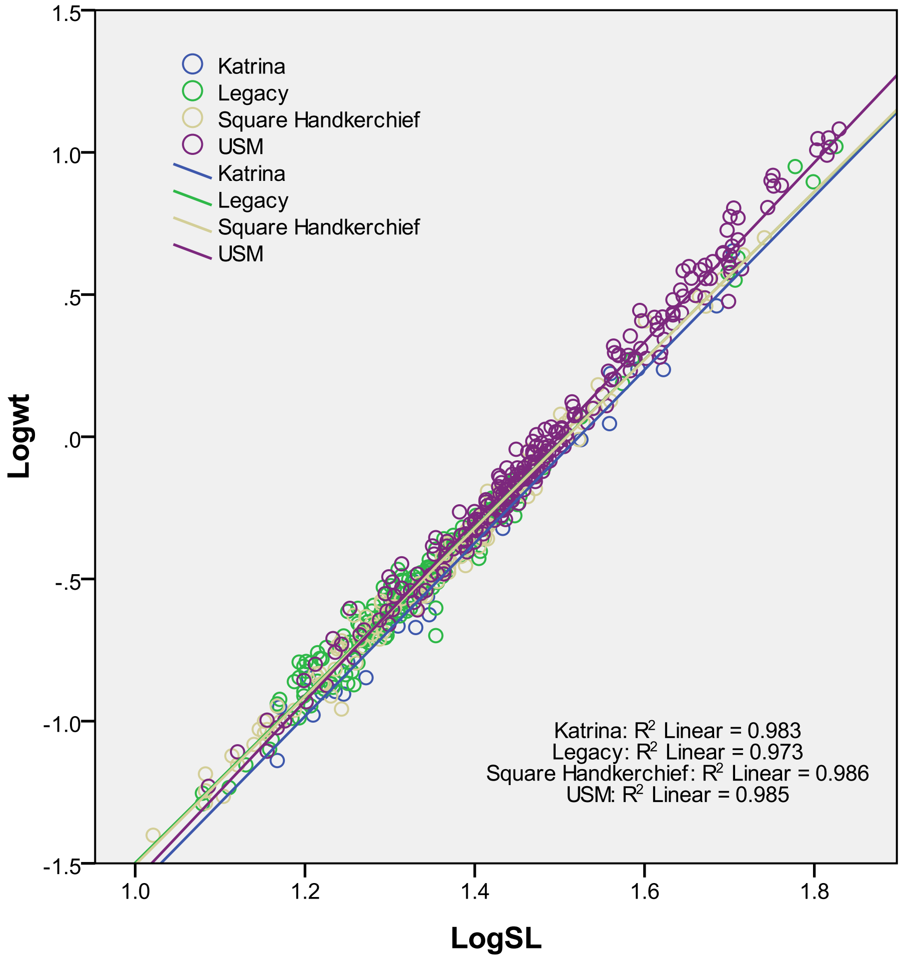


Figure 5. Log$_{10}$-log$_{10}$ transformed Skilletfish (*Gobiesox strumosus*) standard length (SL) wet weight (wt) relationships plotted by reef.

The GT2 method of comparison (Figure 6) showed significant differences in between USM and all other reefs except Katrina, for which the sample size was presumably insufficient to reveal any differences. Projections of weight at SL by reef showed substantially greater weight at SL for larger Skilletfish from USM relative to all other reefs (Figure 7).

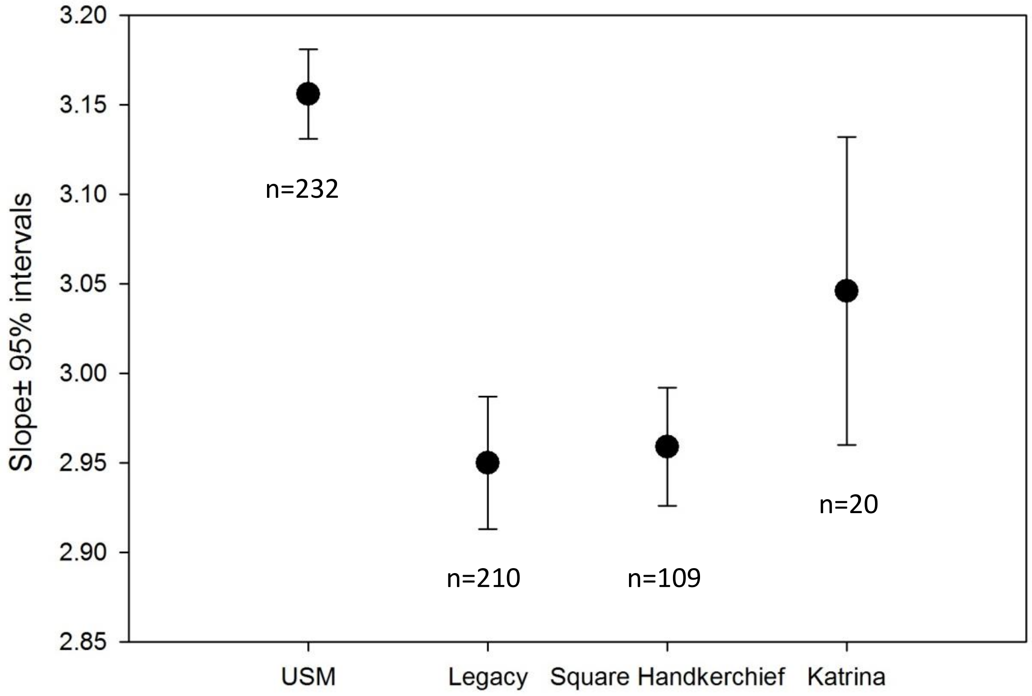


Figure 6. GT2 method-plot comparing slopes of log-log transformed Skilletfish (*Gobiesox strumosus)* standard length – weight relationship regression coefficients by reef at an alpha value of 0.05.

The GT2 test identified no significant differences between the slopes of any of the reefs with the exception of USM. Thus the significant ANCOVA interaction term was mainly driven by the steeper USM $\log_{10}$-$\log_{10}$ SL-weight relationship relative to all other reefs. Once USM data were excluded, ANCOVA showed no significant interaction between the SL covariate and the reef factor ($F_2 = 0.076$, $p = 0.927$). Adjusted mean length at weight differed significantly ($F_2 = 15.444$, $p < 0.001$), pairwise comparison (Table 3) showed fish from Katrina were of poorer condition relative to both Legacy and Square Handkerchief reefs (Figure 8).

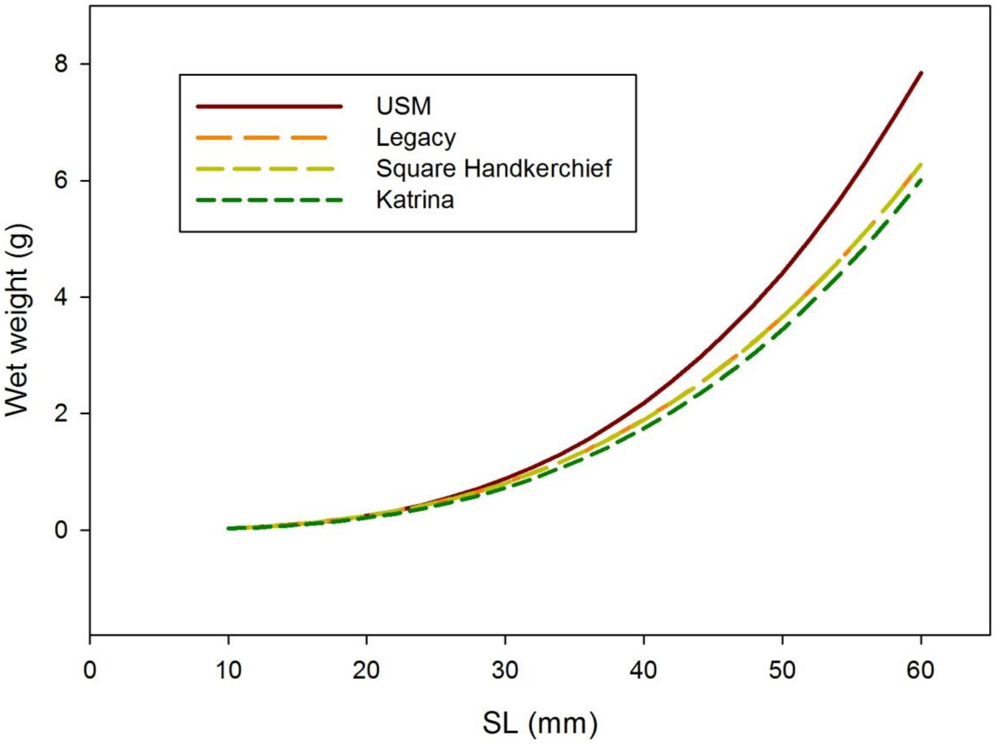


Figure 7. Projected non-transformed weight at length (SL) relationships for Skilletfish (*Gobiesox strumosus*) by reef.

Table 3

Pairwise Comparisons of Skilletfish Condition Among Reefs Without Interaction.

(I) Reef	(J) Reef	Sig.	Adj. Alpha
Katrina	Legacy	<0.001	0.017
	Square Handkerchief	<0.001	0.017
Legacy	Katrina	<0.001	0.017
	Square Handkerchief	0.451	0.050
Square Handkerchief	Katrina	<0.001	0.017
	Legacy	0.451	0.050

Note. Pairwise comparisons of adjusted marginal mean weight at length (21.70 mm SL) for Skilletfish (*Gobiesox strumosus*) among three reefs with parallel length-weight slopes. Mean differences are significant at an adjusted alpha level using a sequential Bonferroni adjustment to an alpha value of 0.05.

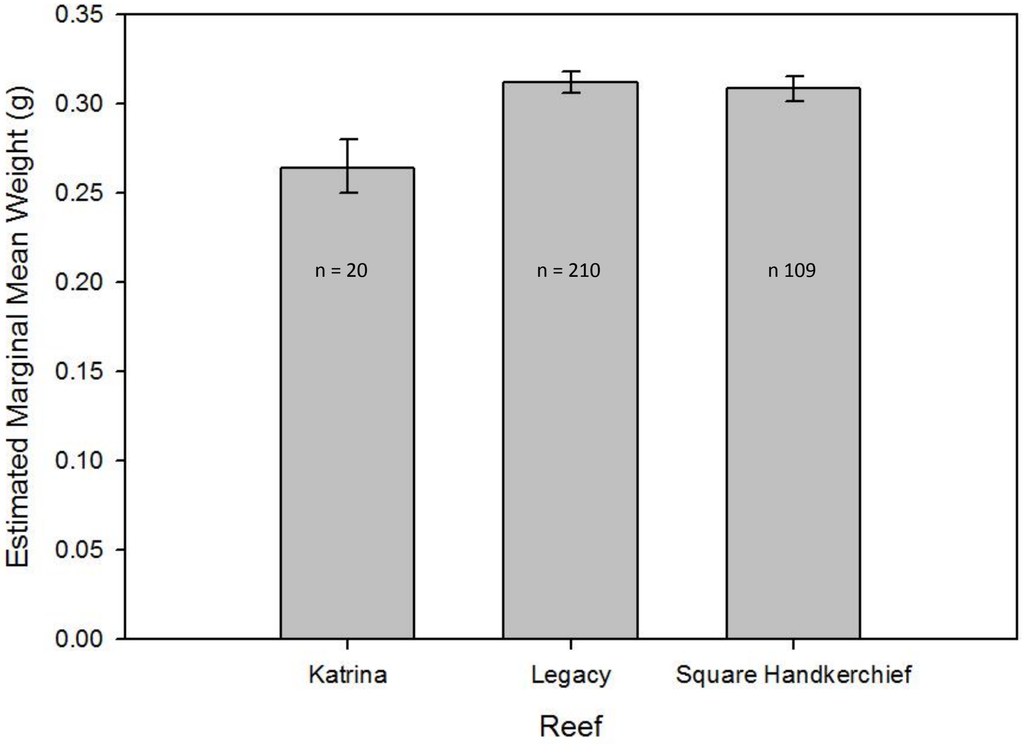


Figure 8. Estimated marginal mean weights (g) for Skilletfish (*Gobiesox strumosus*) at an adjusted mean of 21.70 mm SL, given for three reefs with parallel length-weight slopes. Error bars represent ± two S.E. . Estimated marginal means based on ANCOVA, where $\log_{10}$ wet weight was the dependent variable and $\log_{10}$ standard length was the covariate.

Condition was examined by reef for 126 Gulf Toadfish. Parallel SL-weight relationships were confirmed by the lack of a significant interaction ($F_3 = 1.326$, $p=0.269$) between reef and the SL covariate. The reef factor was significant in the reduced global model ($F_3= 5.571$, $p=0.001$), indicating weight at SL varied by reef. Subsequent, pairwise comparisons of reefs (Table 4) showed no significant differences between Square Handkerchief reef and any other reef; however, weight at SL was significantly lower for Katrina than for both USM and Legacy reefs. Adjusted marginal means did not differ significantly between Legacy and USM for Gulf Toadfish. The condition of Gulf Toadfish from Katrina reef was considerably poorer at an adjusted mean of 34.53 mm SL relative to the condition of fish from both Legacy and USM reefs (Figure 9).

Table 4

Pairwise Comparison of Gulf Toadfish Condition by Reef.

(I) Reef	(J) Reef	Sig.	Adj. Alpha
Katrina	Legacy	0.002	0.010
	Square Handkerchief	0.039	0.013
	USM	0.001	0.008
Legacy	Katrina	0.002	0.010
	Square Handkerchief	0.116	0.017
	USM	0.489	0.050
Square Handkerchief	Katrina	0.039	0.013
	Legacy	0.116	0.017
	USM	0.255	0.025
USM	Katrina	0.001	0.008
	Legacy	0.489	0.050
	Square Handkerchief	0.255	0.025

Note. Pairwise comparisons of Gulf Toadfish (*Opsanus beta*) condition based on estimated marginal adjusted means. Mean differences were significant at an alpha level corrected using the sequential Bonferroni adjustment.

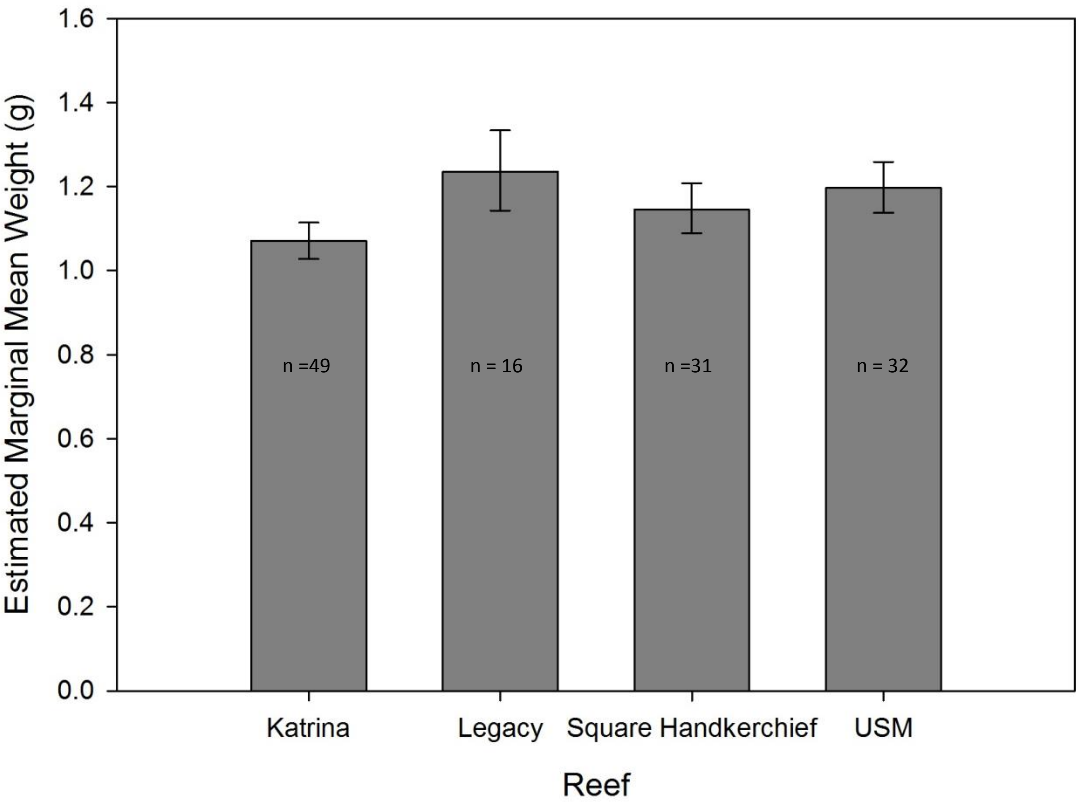


Figure 9. Estimated marginal mean weight (g) for Gulf Toadfish (*Opsanus beta*) by reef at an adjusted standard length of 34.53mm. Error bars represent ± two S.E. Estimated marginal means based on ANCOVA, where $\log_{10}$ wet weight was the dependent variable and $\log_{10}$ SL was the covariate.

The Featherduster Blenny exclusively occurred only at USM and Legacy reefs. Seventy six Featherduster Blennies contributed to a between-reef comparison of condition. Parallel slopes at both reefs were confirmed by the lack of a significant interaction between fish SL and reef (F_3=3.246, *p*=0.076). Levene's Test was significant, however the ratio of variances was very close to 1 (1.04), therefore the ANCOVA results were considered valid. The reduced model revealed a non-significant global effect (F_3= 2.808, *p*=0.098) of reef on Featherduster Blenny condition, although condition was higher at USM reef (Figure 10).

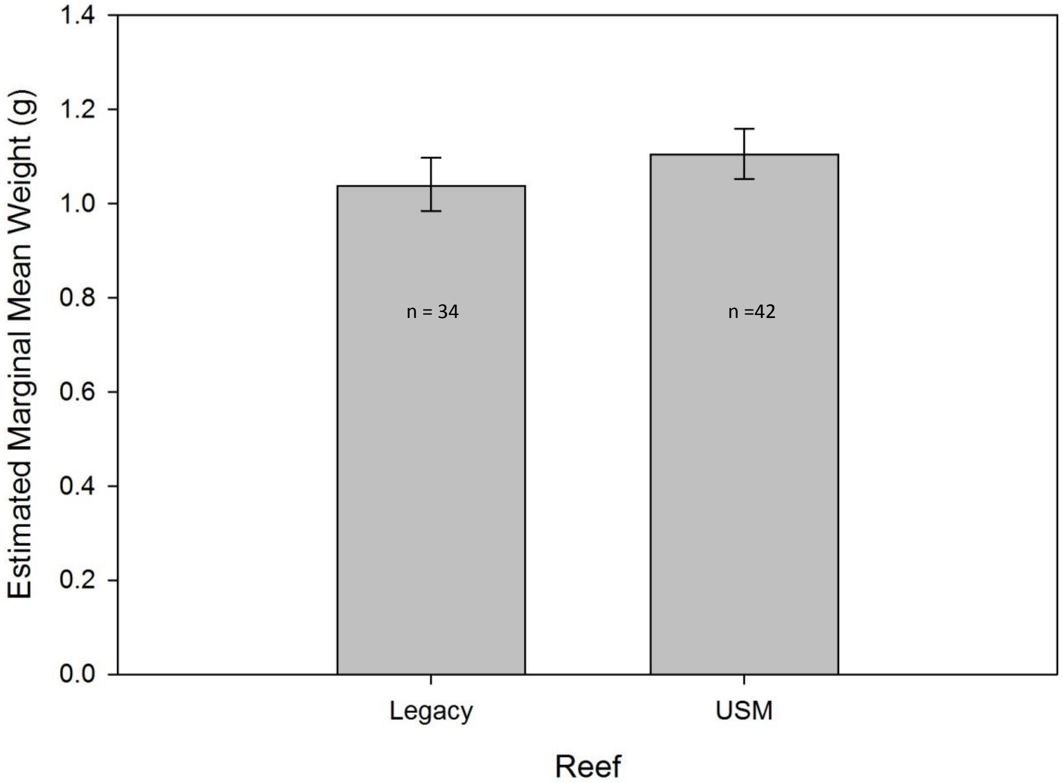


Figure 10. Estimated marginal mean weights (g) of Featherduster Blennies (*Hypleurochilus multifilis*) by reef at an adjusted mean SL of 35.21mm Standard Length. Error bars represent ± two S.E. Estimated marginal means based on ANCOVA, where $\log_{10}$ wet weight was the dependent variable and $\log_{10}$ SL was the covariate.

Condition was compared among reefs using a total of 80 Freckled Blennies collected during the 2012 sampling period. Parallel slopes of Freckled Blenny SL-weight relationships were confirmed by the lack of a significant interaction (F_3=1.203, *p*=0.315) between reef and fish SL. The reef effect was significant in the reduced model (F_3=4.173, *p*=0.009). Subsequent pairwise comparisons of adjusted mean weights (Table 5) among reefs failed to show a significant difference between Katrina and any other reef. However, the adjusted mean weight for Square Handkerchief reef was significantly lower than both Legacy and USM reefs (Figure 11); while adjusted means were non-significant between Legacy and USM reefs.

Table 5

Pairwise Comparison of Freckled Blenny Condition by Reefs

(I) Reef	**(J) Reef**	**Sig.**	**Adj. Alpha**
Katrina	Legacy	0.087	0.013
	Square Handkerchief	0.441	0.050
	USM	0.370	0.025
Legacy	Katrina	0.087	0.013
	Square Handkerchief	0.005	0.008
	USM	0.201	0.017
Square Handkerchief	Katrina	0.441	0.050
	Legacy	0.005	0.008
	USM	0.008	0.010
USM	Katrina	0.370	0.025
	Legacy	0.201	0.017
	Square Handkerchief	0.008	0.010

Note. Pairwise comparison of Freckled Blenny (*Hypsoblennius ionthas*) condition based on adjusted estimated marginal means between reefs. Mean differences are significant at an adjusted alpha level corrected using a sequential Bonferroni adjustment.

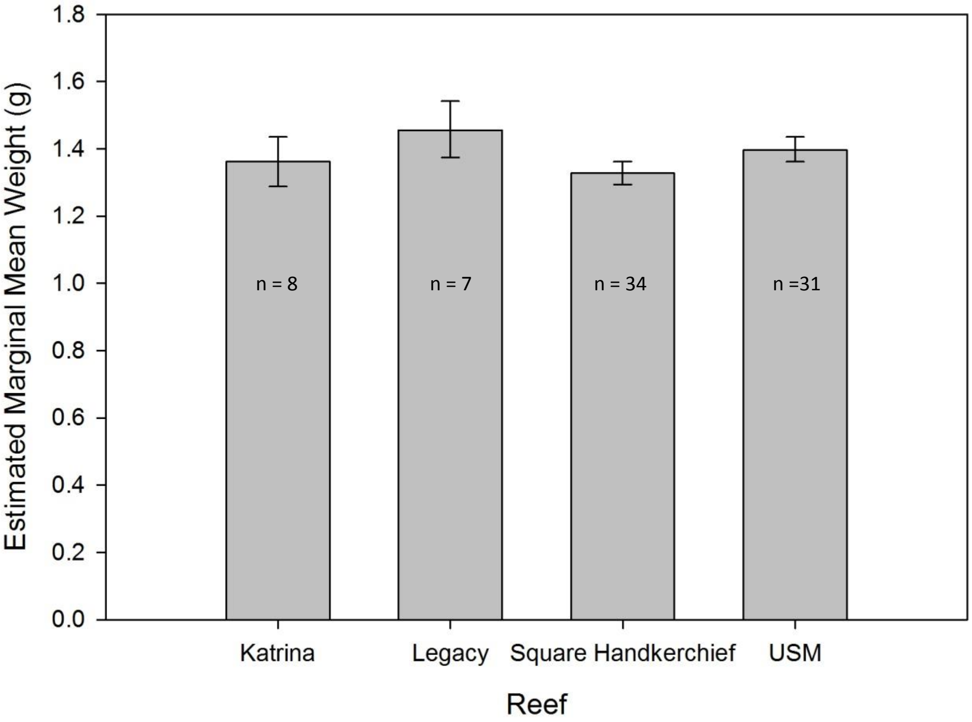


Figure 11. Estimated marginal mean weights (g) of Freckled Blennies (*Hypsoblennius ionthas*) at an adjusted mean of 38.30 mm SL. Error bars represent ± two S.E. Estimated marginal means based on ANCOVA, where $\log_{10}$ wet weight was the dependent variable and $\log_{10}$ SL was the covariate.

The Feather Blenny occurred exclusively on the two low profile reefs. Comparison of condition included SL-weight relationships of the one hundred and thirty six Feather Blennies. Interaction between reef and $\log_{10}$ fish SL factors was non-significant (F_1=0.650, *p*=0.422). The reef factor was significant in the reduced model, reflecting between reef differences in the condition of Feather Blennies (F=29.014, *p*<0.001), with increased weight at SL at USM relative to Legacy reef (Figure 12).

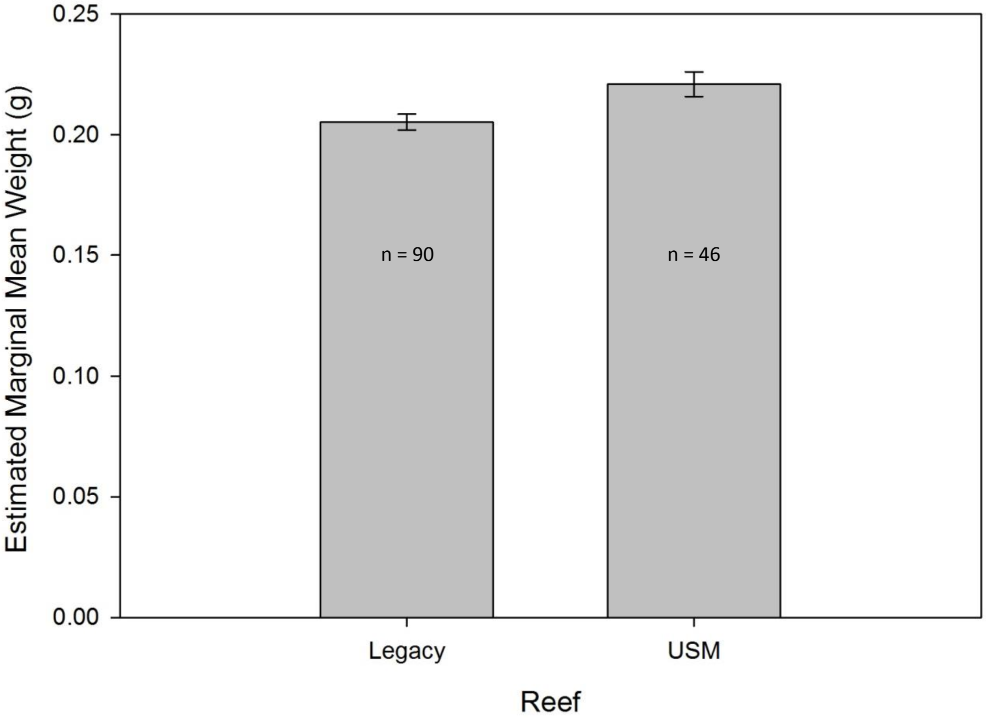


Figure 12. Estimated marginal mean weight (g) of Feather Blennies (*Hypsoblennius hentz*) by reef at an adjusted mean SL of 20.24 mm. Error bars represent ± two S.E. Error bars represent ± two S.E. Estimated marginal means based on ANCOVA, where $\log_{10}$ wet weight was the dependent variable and $\log_{10}$ SL was the covariate

Condition comparison by reef type

Condition of the most common fishes was also compared by the reef type that they were collected from, high profile concrete reefs versus low profile oyster shell reefs The Naked Goby was one of the most abundant resident fishes on the artificial reefs (n= 912). Parallel slopes in the weight at SL relationships for Naked Gobies was confirmed by a non-significant interaction between SL and reef type (F_1=0.85, *p*=0.771). The reef type term in the reduced model was also non significant (F_1=0.654, *p*=0.419) in this species (Figure 13).

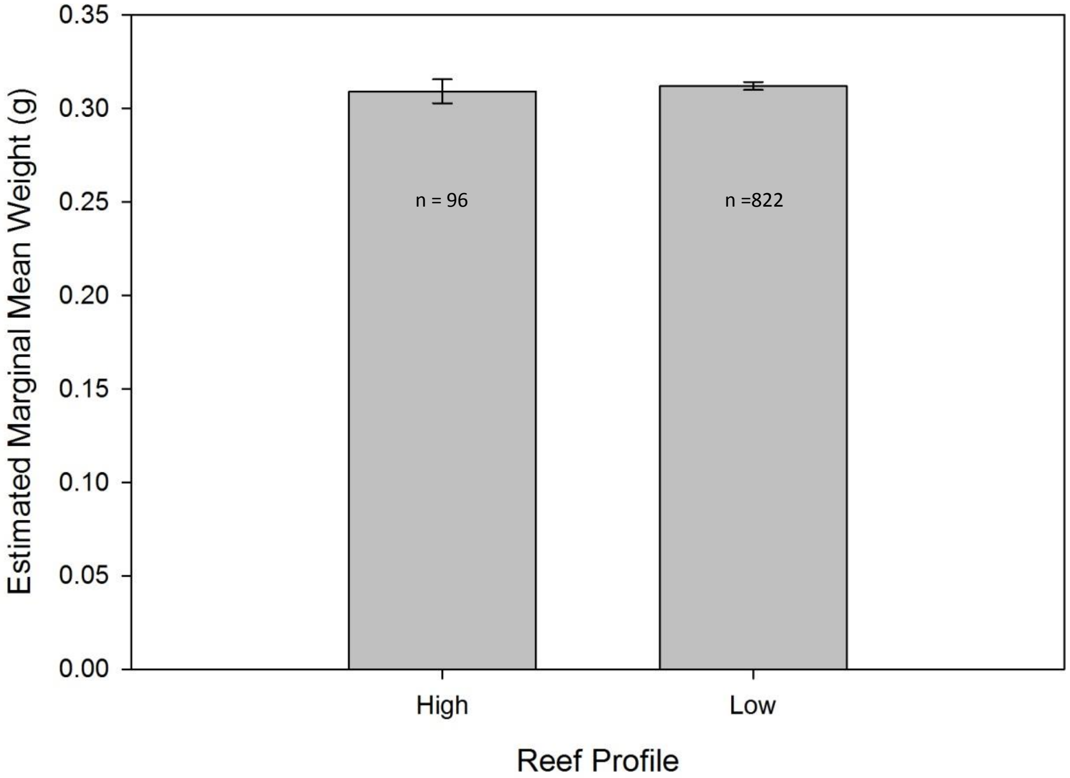


Figure 13. Estimated marginal mean weights (g) of Naked Gobies (*Gobiosoma bosc*) by reef type at an adjusted mean SL of 24.91mm. Error bars represent ± two S.E. Estimated marginal means based on ANCOVA, where $\log_{10}$ wet weight was the dependent variable and $\log_{10}$ SL was the covariate

Another numerically dominant resident fish across all artificial reefs was the Skilletfish (n=549). Non-parallel slopes in SL-weight relationships for Skilletfish between high and low profile types (F_1=13.63, p<0.001) indicate a significant interaction reef type (Figure 14). The rate at which $\log_{10}$ weight increased with $\log_{10}$ SL was greater at low profile reefs for Skilletfish, because larger fish were heavier than similar length fish from high profile reefs.

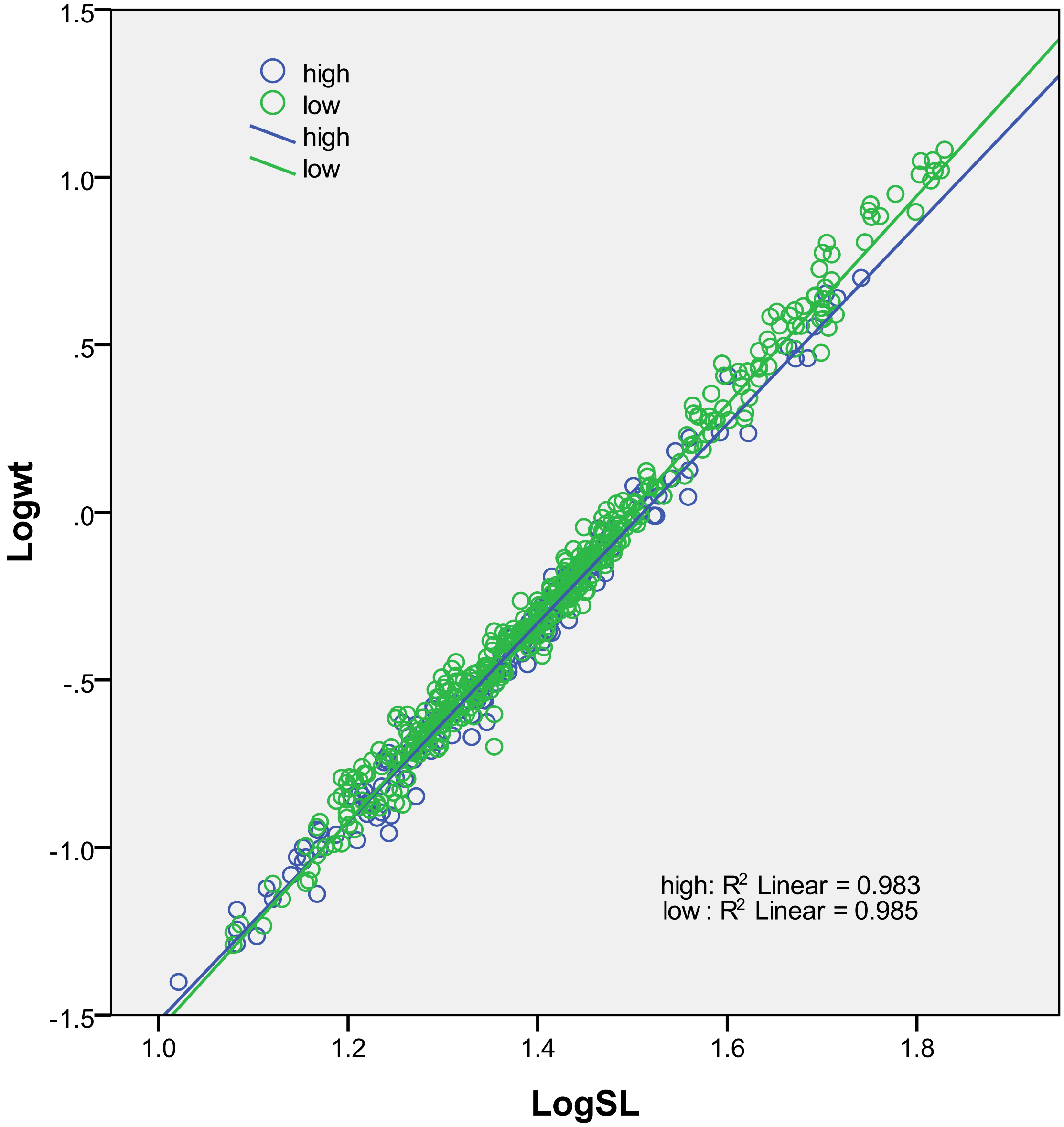


Figure 14. Log_{10}-log_{10} transformed Skilletfish (*Gobiesox strumosus*) standard length (SL) - wet weight (wt) relationships plotted by reef type.

For the Gulf Toadfish (n=126), slopes in weight at SL relationships were parallel between reef types, as shown by a non-significant ANCOVA interaction term (F_1=0.105, *p*=0.746). Condition was poorer at high profile reefs than at low profile reefs for Gulf Toadfish, as shown by significant main effects (F_1=11.628, *p*<0.001) (Figure 15).

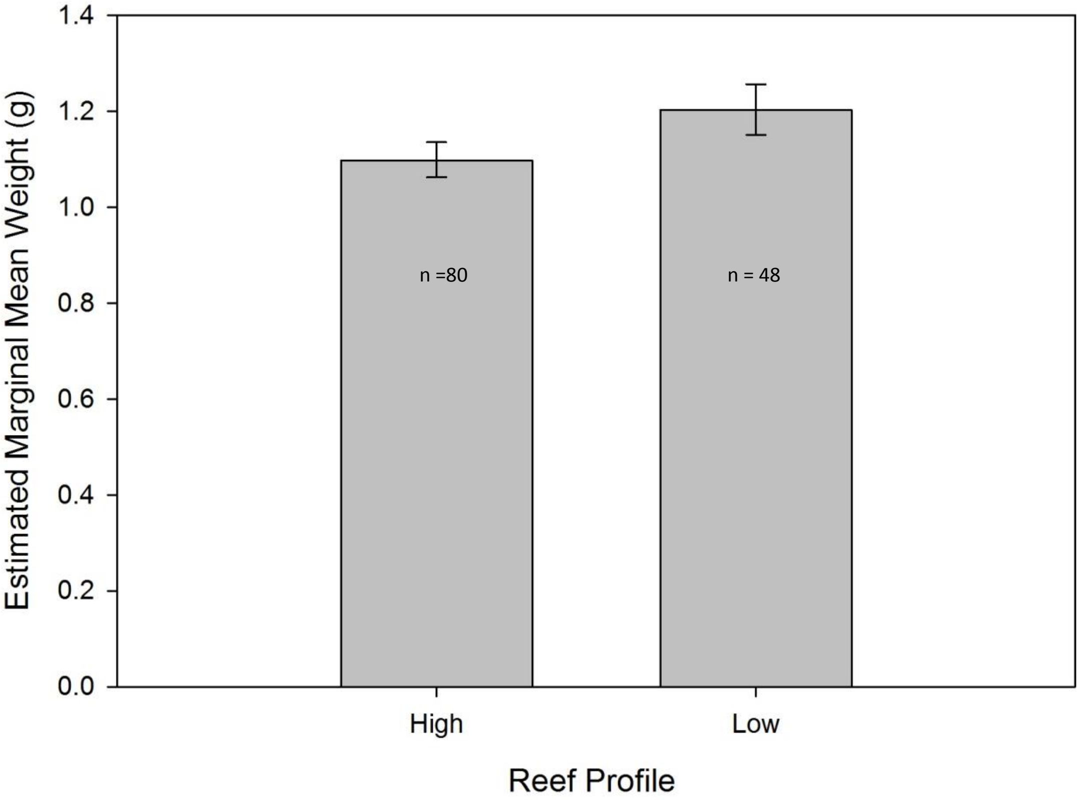


Figure 15. Estimated marginal mean weights (g) of Gulf Toadfish (*Opsanus beta*) by reef profile type at an adjusted mean SL of 34.53mm. Error bars represent ± two S.E. Estimated marginal means based on ANCOVA, where $\log_{10}$ wet weight was the dependent variable and $\log_{10}$ SL was the covariate

Parallel slopes in weight at SL relationships relative to reef type for the Freckled Blenny (n=80), was confirmed by a non-significant interaction term between reef type and SL (F_1=0.098, *p*=0.755). Again, condition was significantly poorer for this species at high profile reefs, as shown by a significant effect for the reef type factor (F_1=10.238, *p*=0.002) (Figure 16).

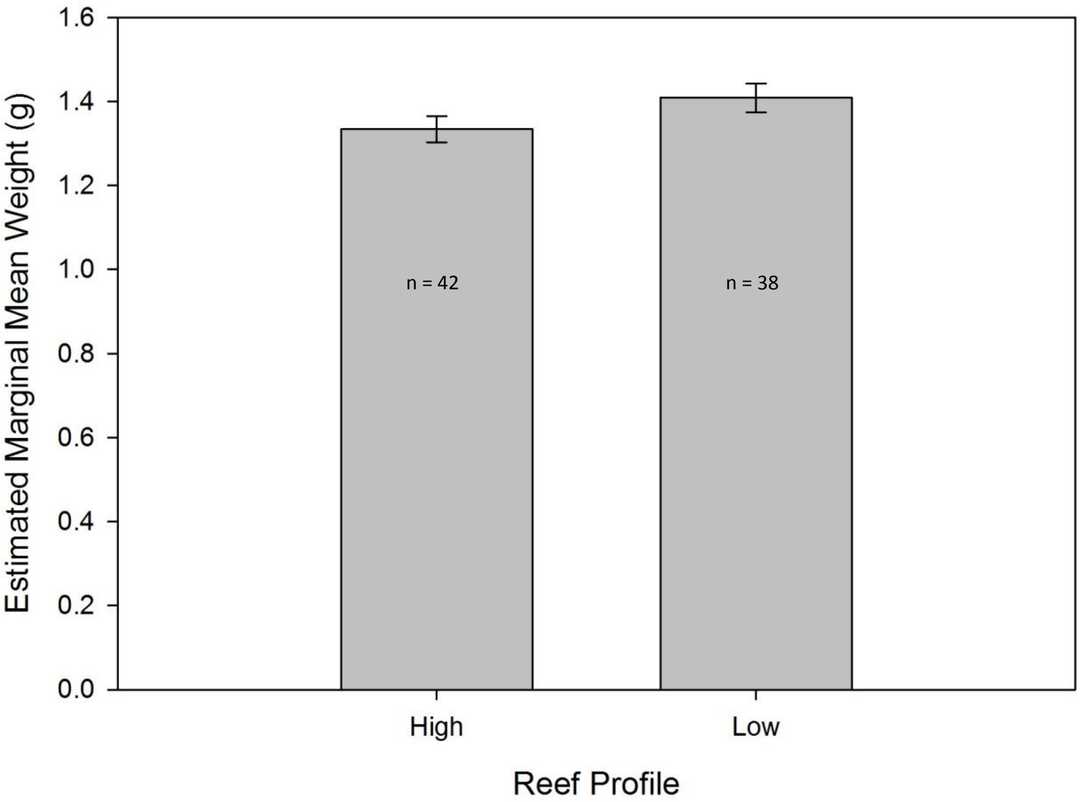


Figure 16. Estimated marginal mean weight (g) of Freckled Blennies (*Hypsoblennius ionthas*) by reef type at an adjusted mean SL of 38.30mm. Error bars represent ± two S.E. Estimated marginal means based on ANCOVA, where $\log_{10}$ wet weight was the dependent variable and log SL_{10} was the covariate

Condition Comparison by Subregion

Condition was also compared between eastern and western subregions for the six most abundant species. Parallel slopes in weight at SL relationships for Naked Gobies (n=912) were indicated by a non-significant interaction (F_1=0.854, *p*=0.356) between subregion group and SL. The subregion factor was also non-significant (F_1=0.429, *p*=0.512) for this species (Figure 17).

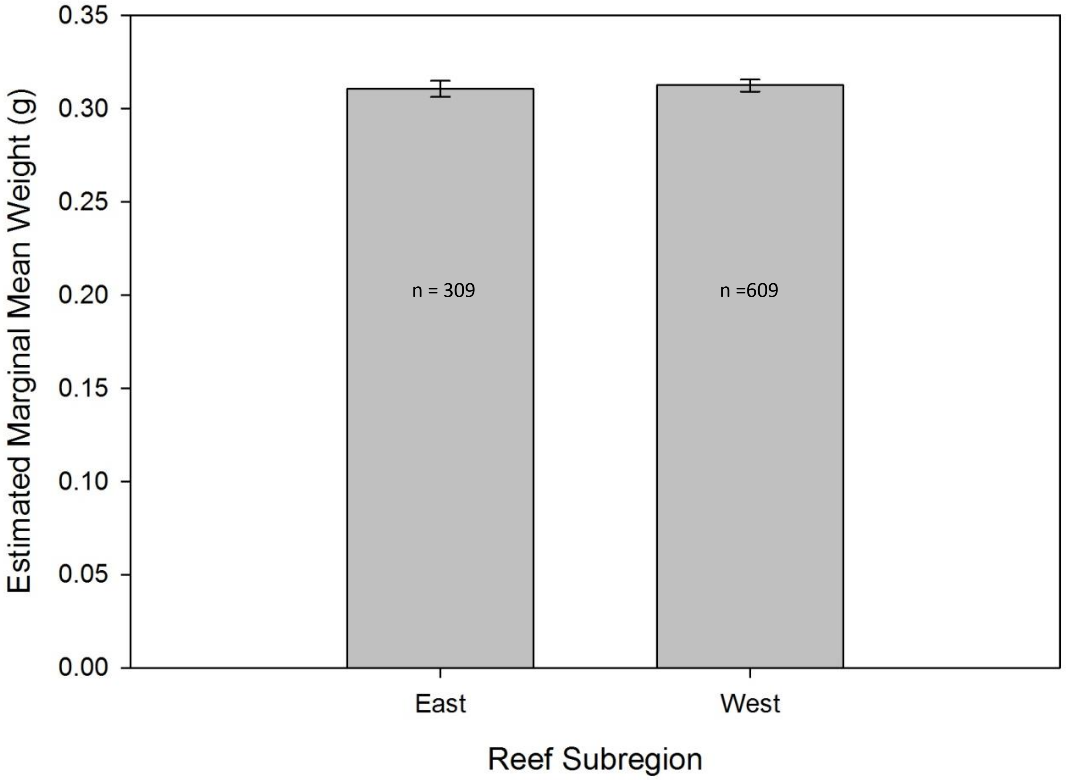


Figure 17. Estimated marginal mean weight (g) of Naked Gobies (*Gobiosoma bosc*) by subregion at an adjusted mean SL of 24.91mm. Error bars represent ± two S.E. Estimated marginal means based on ANCOVA, where $\log_{10}$ wet weight was the dependent variable and $\log_{10}$ SL was the covariate

Different trajectories in weight at SL relationships between subregions for the Skilletfish (n=549), were shown by the significant interaction (F_1=19.111, p <0.001) between subregion and SL. Large fish from the western subregion were in relatively better condition than those from eastern reefs (Figure 18).

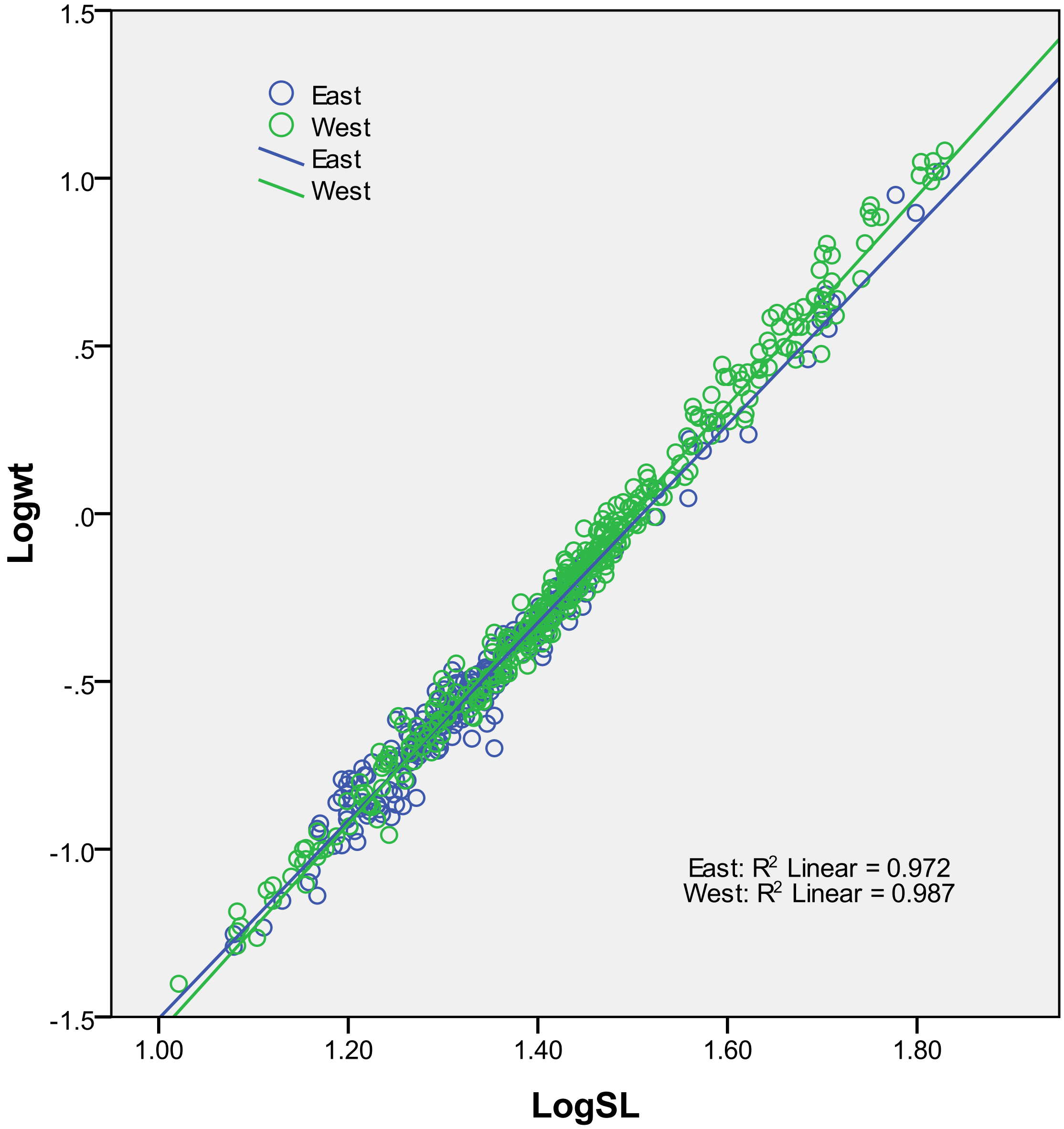


Figure 18. Interaction plot showing $\log_{10}$-$\log_{10}$ standard length (SL)-wet weight (wt) relationships for Skilletfish (*Gobiesox strumosus*) by the reef subregion.

Parallel slopes in the weight at SL relationship for the Gulf Toadfish (n=126), between subregions was confirmed by the non-significant interaction term (F_1=0.106, *p*=0.745) between SL and subregion. A significant subregion term for Gulf Toadfish in the reduced model (F_1=4.663, *p*=0.033) reflected higher weights for fish from western reefs relative to reefs in the eastern sound (Figure 19).

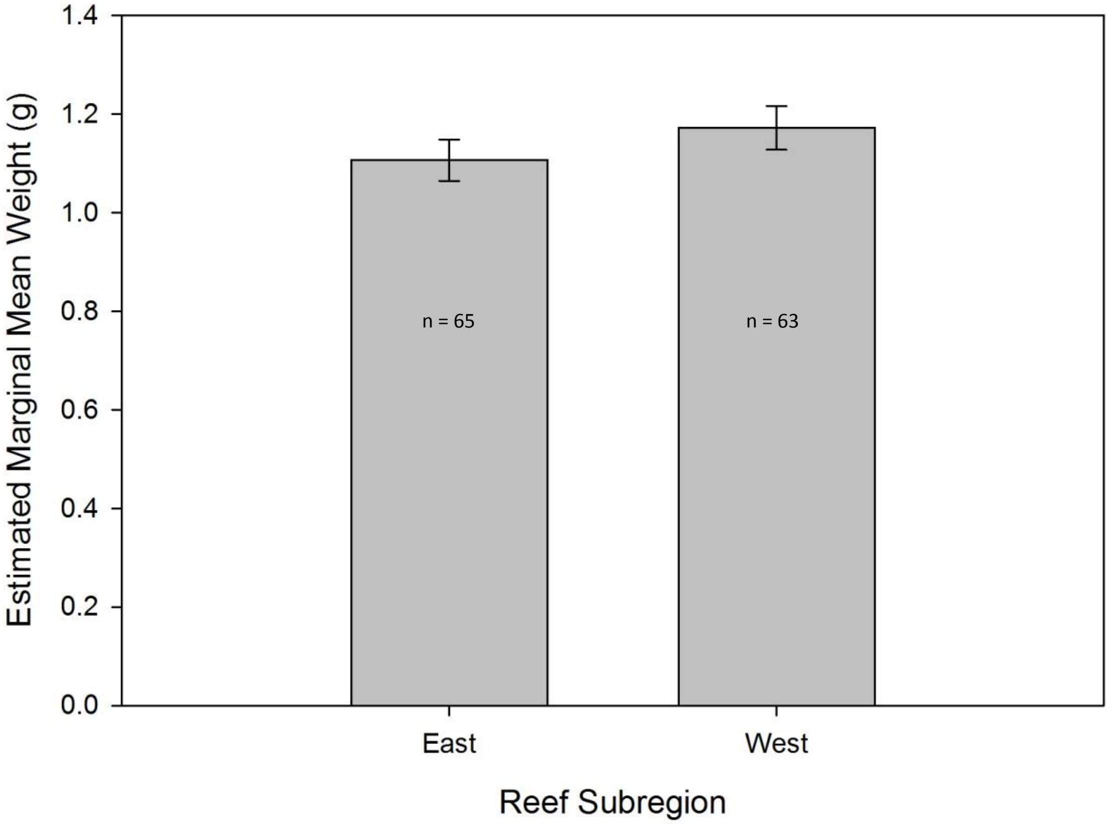


Figure 19. Estimated marginal mean weights (g) of Gulf Toadfish (*Opsanus beta*) by subregion at an adjusted mean SL of 34.53mm. Error bars represent ± two S.E. Estimated marginal means based on ANCOVA, where $\log_{10}$ wet weight was the dependent variable and $\log_{10}$ SL was the covariate

For the Freckled Blenny (n=80), parallel slopes between subregions, was confirmed by the non-significant ANCOVA interaction term (F_1=1.528, *p*=0.220). The subregion factor was also non-significant for this species (F_1=1.809, *p*=0.183) with no significant difference between estimated marginal mean weights at length when compared between subregion groups (Figure 20).

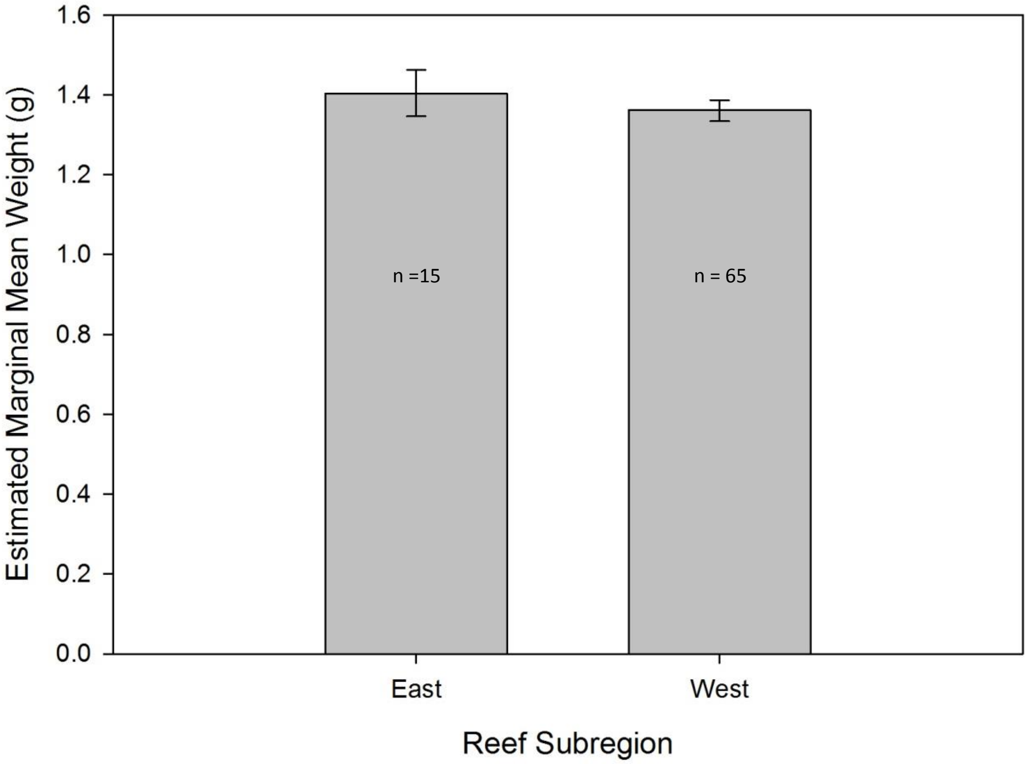


Figure 20. Estimated marginal mean weights (g) for Freckled Blennies (*Hypsoblennius ionthas*) by reef subregion at an adjusted mean SL of 38.30mm. Error bars represent ± two S.E. Estimated marginal means based on ANCOVA, where $\log_{10}$ wet weight was the dependent variable and $\log_{10}$ SL was the covariate

Table 6

Summary of Weight at Length (SL) Difference Estimates by Reef and Species

Species	**Reef**	**Estimated Marginal Mean Weight (EMMW) (g)**	**SL (mm)**	**% EMMW increase**
Gobiosoma bosc	Katrina	0.2831	24.91	
	USM	0.3119	24.91	10.15%
	Legacy	0.3119	24.91	10.15%
	Square Handkerchief	0.3126	24.91	10.41%
Hypsoblennius hentz	Legacy	0.2051	20.24	
	USM	0.2208	20.24	7.65%

Table 6 (continued).

Species	**Reef**	**Estimated Marginal Mean Weight (EMMW) (g)**	**SL (mm)**	**% EMMW increase**
Hypsoblennius ionthas	Square Handkerchief	1.3274	38.30	
	USM	1.3964	38.3	5.20%
	Legacy	1.4555	38.3	9.65%
Opsanus beta	Katrina	1.0715	34.5	
	USM	1.1967	34.5	11.69%
	Legacy	1.2359	34.5	15.35%
Gobiesox strumosus	Katrina	0.2642	21.7	
	Square Handkerchief	0.3083	21.7	14.13%
	Legacy	0.3119	21.7	18.03%
	USM*	0.3167	21.7	19.86%

Note. Summary of weight at SL difference estimates by species for significantly different reef groups based on ANCOVA, followed by sequential Bonferroni adjusted pairwise tests. Estimated marginal mean weights are based on ANCOVA unless indicated by an asterisk. Where marked by an asterisk significant interactions exist between reef groups and the SL covariate as indicated by ANCOVA and weight at SL estimates are calculated based on regression coefficient parameters at the same SL as ANCOVA estimates. EMMW increase reflects a percentage of body weight relative to the reef group with the lowest weight at SL for each species.

A summary of the weight SL increase where significant differences exist shows no consistent pattern in condition difference among individual reefs across species (Table 6). However, the poorest condition individuals for a species always occur on one of the high profile reefs when that species occurred on that reef.

Diet Comparisons

A total of 531 fish collected from the substrate baskets were available for diet analysis. Of these, Skilletfish (n=284) was the most numerous species across all reef locations. Consequently, a total of 168 Skilletfish were selected for diet analysis, consisting of 101 small (<30 mm SL), 39 medium (30 – 45 mm SL) and 28 large (> 45 mm SL) fish. Fifteen of these fish were obtained from Katrina reef, 38 from Legacy, 39 from Square Handkerchief, and 76 from USM reef. Of the 168 digestive tracts examined, two contained only amorphous material and 23 (13.7 %) were empty. These included 13.3 % of the fish from Katrina reef, 7.89% from Legacy reef, 25.64% from Square Handkerchief, and 10.53% from USM reef.

Prey Species Accumulation

The shape of the prey species accumulation curve describes the increase in diet diversity with increasing numbers of samples, such that level curves imply a sufficient sample size has been reached to completely describe the diet diversity of the target group. Diet richness and sample size were also assessed with sample diet richness as a percentage of estimated diet richness, S(est) (Table 7).Where diet richness is well represented according to the species accumulation curve and percentage of S(est), it may be compared among samples to discern differences in diet richness among samples (Ballard and Rakocinski 2012). According to S(est) values, Skilletfish diets were least rich at Katrina reef where the observed number of prey taxa was lowest (17 prey taxa observed), somewhat more rich at Square Handkerchief (21 prey taxa observed), more rich at USM (30 prey taxa observed), and most rich at Legacy (32 prey taxa observed) (Figure 21). Diet richness was apparently least well represented for Legacy reef, as its cumulative prey diversity percentage was low at 53 percent of S(est) (Figure 7). Thus, diet diversity was less well represented for Legacy reef relative to other reefs (71-77 percent), despite the relatively large sample size compared to the two high profile reefs. Therefore, diets of Skilletfish from low profile reefs appeared to be generally broader than from fish on high profile reefs. As a whole, Skilletfish diets were generally well represented at the artificial reefs when samples from all four reefs were pooled. When compared to Legacy reef which represented the highest diet richness among reefs individually, the pooled samples indicated a comparatively wider total diet breadth for Skilletfish . This suggests that while diets richness was lower in reefs other than Legacy, diets were composed of some different prey taxa contributing to a higher total species richness overall.

Table 7

Percentage of Skilletfish Diet Taxa Sampled Based on Estimated Diet Richness

Reef	**Number of diets sampled**	**Diet richness**	**S(est)**	**S(est) lower C.I.**	**S(est) upper C.I.**	**% of S(est)**
USM	68	30	38.86	19.39	58.32	77.20
Katrina	13	17	22.65	11.79	33.51	75.06
Square Handkerchief	26	21	29.65	10.73	48.57	70.83
Legacy	35	32	60.07	22.77	97.37	53.27

Note. Estimated species richness, S(est,) and S(est) 95% C.I. was calculated from extrapolated rarefaction curves based on 100 iterations of random sample order of the sampled diets. The estimated percentage of diet species richness sampled, % of S(est), is given as a percentage of S(est) represented by the sample species richness relative to a stable S(est) for the attenuated asymptotic curve.

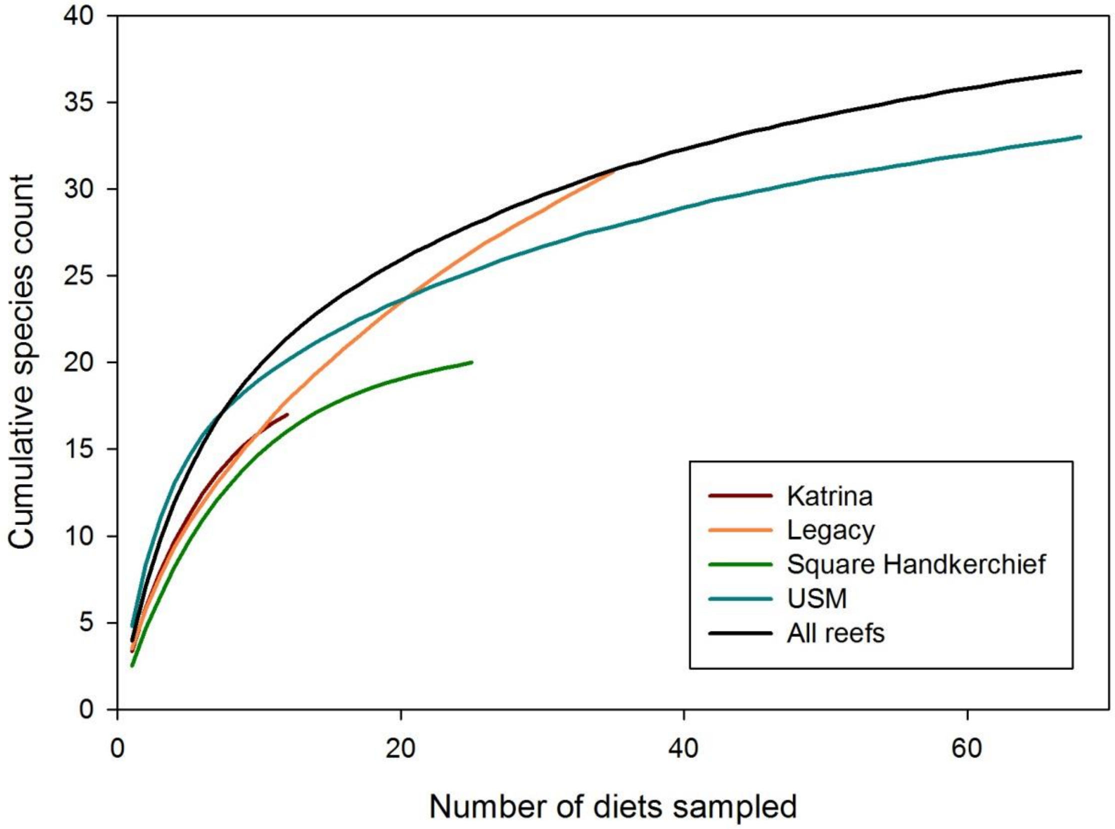


Figure 21. Skilletfish (*Gobiesox strumosus*) prey species-accumulation curves by reef, calculated using the average of 999 permutations of a randomized ordering of diets.

Diet Volume

Parallel slopes in $\log_{10}$ diet volumes between $\log_{10}$ SL and reef was confirmed by a non-significant ANCOVA interaction ($F_3 = 0.203$, $p=0.894$). A significant Levene's test ($F_{3,139} = 2.896$, $p=0.037$) suggested a degree of heterogeneity of variance in diet volume among reefs. However, as the ratio of group variances was less than three (2.27), the homogeneity assumption of ANCOVA was not considered compromised. The reef factor was significant ($F_3 = 5.878$, $p=0.001$); thus, pairwise comparisons were made among reefs (Table 8). Pairwise comparisons showed significantly larger mean diet volume in USM Skilletfish relative to Skilletfish from Square Handkerchief reef, and while non-significant, an increase in diet volume from Square Handkerchief relative to Katrina and Legacy reef fish (Figure 22).

Table 8

Pairwise Comparison of Skilletfish Diet Volume Between Reefs

(I) Reef	(J) Reef	Sig.	Adj. Alpha
Katrina	Legacy	0.978	0.050
	Square Handkerchief	0.083	0.017
	USM	0.213	0.025
Legacy	Katrina	0.978	0.050
	Square Handkerchief	0.020	0.010
	USM	0.078	0.013
Square Handkerchief	Katrina	0.083	0.017
	Legacy	0.020	0.010
	USM	<0.001	0.008
USM	Katrina	0.213	0.025
	Legacy	0.078	0.013
	Square Handkerchief	<0.001	0.008

Note. Pairwise comparisons of log diet volume between reefs, controlling for fish SL as a covariate. Mean differences are significant at an adjusted alpha level corrected using a sequential Bonferroni adjustment.

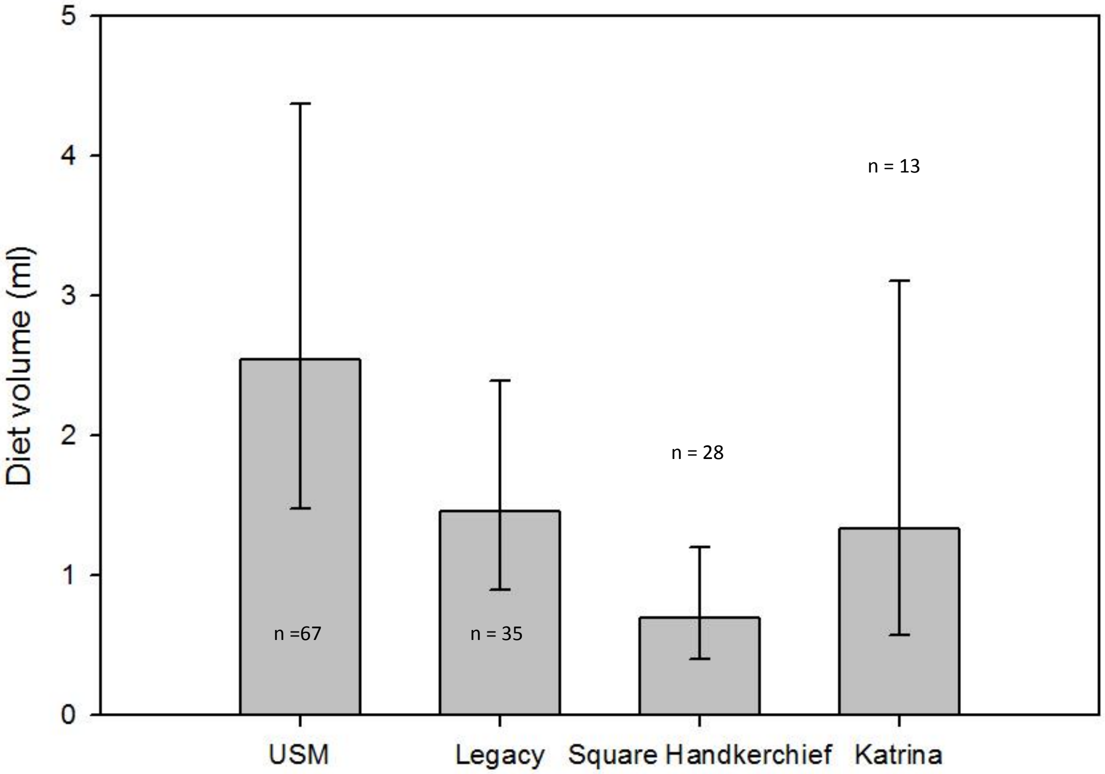


Figure 22. Estimated marginal mean diet volume (ml) of Skilletfish (*Gobiesox strumosus*) by reef assessed at an adjusted mean SL of 29.11 mm. Error bars represent ± two S.E. Estimated marginal means based on ANCOVA, where $\log_{10}$ diet volume was the dependent variable and $\log_{10}$ SL was the covariate.

Parallel slopes in the diet volume response for Skilletfish was also confirmed for the reef type comparison by a non significant ($F_1 = 0.920$, p=0.339) interaction between reef type and fish SL. The reef type factor was highly significant (F_1= 10.899, p=0.001), reflecting the estimated marginal mean diet volume was two-fold higher at low profile reefs when grouped than at the high profile reefs (Table 9).

Table 9

Comparison of Skilletfish Diet Volume by Reef Type.

			95% Confidence interval	
Reef type	**Mean**	**Std. Error**	**Lower**	**Upper**
High	1.033	1.216	0.702	1.517
Low	2.228	1.130	1.754	2.831

Note. Skilletfish (*Gobiesox strumosus*) estimated marginal mean diet volume compared by reef type. Estimated marginal mean diet volumes were evaluated at an adjusted mean SL of 29.11 mm.

Differences in diet composition in terms of prey volume were apparent by individual reef (Figure 23); harpacticoid copepods made up a comparatively large proportion of Legacy diets (17.80 %) but were negligible on all other reefs. Caprellid amphipods were an important diet item only on Katrina reef where they made up 8.27% of diets by volume. Square Handkerchief diets were clearly differentiated by the importance of Corophiidae, making up 21.11% of mean diet volume, and a small proportion at all other reefs. USM reef notably appears more diverse than any other reef; aside from xanthid crabs which were prevalent in diets across all reefs except Katrina, all other diet taxa made up small mean proportions of diet volume.

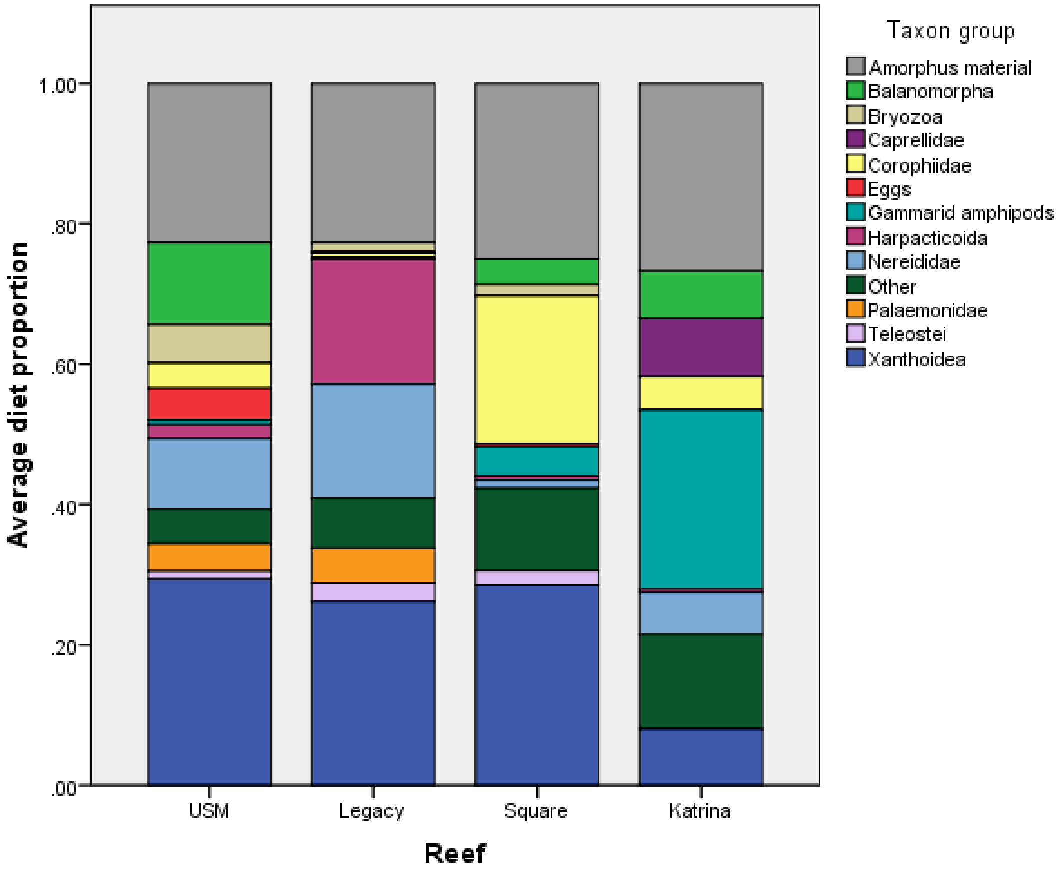


Figure 23. Diet composition of Skilletfish (*Gobiesox strumosus*) summarized as a mean of prey type proportions across individuals by reef.

When diet composition in terms of prey volume is compared between reef types, some within group similarities were apparent for low profile reefs (Figure 23); Palaemonidae were present only at low profile diets, although they did not make up as large a percentage of volume. Nereids occurred in diets from all reefs, but they made up a larger volume of low profile reef diets. High profile diets were instead dominated by amphipods, including Caprellids, Coropiidae and Gammaridea, all of which were absent or made up a trivial percentage of volume at low profile diets. The taxonomic make up of amphipods also appeared to differ between subregion, with corophiid amphipods dominating Square Handkerchief diets, whereas Gammaridean and Caprellid amphipods were more important diet items for Katrina fish.

Diet ANOSIM

The Two-Way Analysis of Similarity (ANOSIM) on the effect of the size class factor crossed with reef type showed a significant global difference in diet composition of Skilletfish. Significant differences existed among size class groups averaged across reefs with a large degree of overlap between groups as indicated by a low R value (R= 0.177, *p* = 0.001). For reef groups averaged across size classes there were significant differences with a larger non-overlap between groups (R = 0.311, *p* = 0.001). Follow-up pairwise comparisons showed significant difference in diet composition for small fish relative to large and medium size classes, but no difference between diets of large and medium size class Skilletfish (Table 10). In addition, pairwise comparisons of diet composition proved significant between all four reefs (Table 11).

Table 10

Pairwise Comparison of Skilletfish Diet Composition by Size Class

Groups	**R Statistic**	**Significance**	**Adjusted alpha**	**Actual Permutations**	**Number of permutations ≥ observed**
Large, Medium	0.002	0.456	0.050	999	455
Small, Medium	0.111	0.011	0.025	999	10
Large, Small	0.303	0.001	0.017	999	0

Note. Pairwise comparisons of Skilletfish (*Gobiesox strumosus*) diet composition by size classes as part of a Two Way ANOSIM of Reef crossed with Size class. Alpha values of 0.05 were adjusted with the sequential Bonferroni method.

Table 11

Pairwise Comparisons of Skilletfish Diet Composition Between Reefs

Groups	R Statistic	Significance	Adjusted Alpha	Actual Permutations	Number of permutations ≥ observed
Katrina, Square Handkerchief	0.103	0.027	0.050	999	26
Katrina, Legacy	0.422	0.001	0.008	999	0
Katrina, USM	0.429	0.001	0.008	999	0
Legacy, Square Handkerchief	0.338	0.001	0.008	999	0
Legacy, USM	0.219	0.001	0.008	999	1
Square Handkerchief, USM	0.303	0.001	0.008	999	0

Note. Pairwise comparisons of Skilletfish (*Gobiesox strumosus*) diet composition between reefs as part of a Two-Way ANOSIM for reef crossed with size class. Alpha values of 0.05 were adjusted with the sequential Bonferroni method.

The global Two-Way ANOSIM testing for differences in diet composition by reef type crossed with size class showed both the reef type (R = 0.124, p=0.001), as well as the size-class factor (R = 0.319, p=0.001) were significant, although the size class R value indicated a large overlap between groups. Follow-up pairwise tests between size classes when grouped by reef type revealed significant differences in diet composition between small size class and both the medium and the large size classes (Table 12).

Table 12

Pairwise comparison of Skilletfish diet composition between size classes.

Groups	**R Statistic**	**Significance**	**Adjusted alpha**	**Actual Permutations**	**Number of permutations ≥ observed**
Large, Medium	0.030	0.253	0.050	999	252
Small, Medium	0.087	0.001	0.017	999	0
Large, Small	0.257	0.001	0.017	999	0

Note. Pairwise comparisons of Skilletfish (*Gobiesox strumosus*) diet composition among size classes, conducted as part of a Two-Way ANOSIM for Profile crossed with Size class. Alpha values of 0.05 were adjusted with the sequential Bonferroni method.

Finally, a global Two-Way Analysis of Similarity (ANOSIM) testing for differences in diet composition by subregion crossed with size class revealed significant effects for both subregion (R= 0.142, *p*=0.001) and size class (R= 0.112, *p*=0.001) however, differences were small in both cases as indicated by low R values. Pairwise comparison of size classes showed no significant differences in diet composition between small and medium size classes of Skilletfish; however, the diet composition of the small and large size classes differed significantly (Table 13).

Table 13

Pairwise Comparison of Skilletfish Diet Composition Between Size Classes

Groups	**R Statistic**	**Significance**	**Adjusted alpha**	**Actual Permutations**	**Number of permutations ≥ observed**
Large, Medium	0.015	0.352	0.050	999	351
Small, Medium	0.047	0.095	0.025	999	94
Large, Small	0.180	0.001*	0.017	999	0

Note. Pairwise comparison of Skilletfish (*Gobiesox strumosus*) diet composition between size classes as part of a Two-Way ANOSIM; subregion crossed with size class group. Alpha values of 0.05 were adjusted with the sequential Bonferroni method.

Diet SIMPER Analysis

Similarity percentage (SIMPER) analysis was used to identify the degree to which diet items were responsible for the significant differences in diet composition detected by ANOSIM. SIMPER comparisons of diets by reef showed a low degree of within reef similarity, ranging from 9.52 for Square Handkerchief to 25.67 for Katrina reef. A low degree of similarity and low similarity/SD (See Appendix) indicates a broad diet and a lack of specific diet items that may be said to be characteristic of that group. Conversely, dissimilarity between reefs was very high, with 87.79 being the lowest degree of dissimilarity observed. Tables 14 to 19 list the prey types which contributed the greatest percentage of dissimilarity between diets of fish by pairwise comparison of reefs. Katrina reef Skilletfish diets were primarily distinguished from diets on all other reefs by the presence of *Hourstonius laguna*, which contributed between 16.72% and 17.93% of total dissimilarity in each comparison with Katrina (Tables 14, 15 and 17). Legacy reef diets were defined most strongly by the contribution of *Neanthes succinea* to dissimilarity to other reefs, which ranged from 10.40% to 12.90% of total diet dissimilarity by reef (Tables 14, 16, and 18). Square Handkerchief diets were distinguished as different from other reefs by different prey taxa depending on the comparison. Square Handkerchief was differentiated from Katrina (Table 14.) by the comparatively large volume of *Eurypanopeus depressus* and presence of *Apocorophium louisianum*, which were responsible for 8.17% and 8.02% of dissimilarity respectively. When compared to Legacy (Table 16) and USM (Table 19) reefs, Square Handkerchief diets were defined by the presence of relatively large volumes of *A. louisianum* and crab zoea, contributing 8.17% and 6.04% of dissimilarity, respectively, to Legacy, and 8.59% and 5.78% to USM diet dissimilarity. USM when compared to Katrina (Table 17) was most strongly separated by the volume of *E. depressus* present in USM diets which accounted for 9.54% of between reef dissimilarity. USM and Legacy diets show the poorest differentiation with dissimilarity of only 87.79 (Table 18). The taxon group which differentiates USM from Legacy best is *Balanus* spp, accounting for 5.32% of dissimilarity. USM diets were best defined from those of Square Handkerchief by the volume of *Balanus* spp. and *N. succinea* (Table 19) responsible for 6.86% and 6.28% of dissimilarity, respectively.

Table 14

SIMPER Analysis Comparison of Skilletfish Diet Dissimilarity Between Katrina and Legacy Reefs

Species	**Katrina - average proportion**	**Legacy - average proportion**	**Average dissimilarity**	**Dissimilarity/ SD**	**Contribution %**	**Cumulative contribution**
Hourstonius laguna	0.47	0.01	16.65	1.26	17.93	17.93
Neanthes succinea	0.11	0.27	10.80	0.72	11.63	29.56
Unidentifie tegastidae	0.01	0.27	9.18	0.71	9.88	39.45
Unidentified xanthidae	0.11	0.17	7.75	0.71	8.35	47.79
Unidentified megalopae	0.13	0.11	6.87	0.64	7.40	55.20
Eurypanopeus depressus	0.06	0.16	6.73	0.55	7.24	62.44
Paracaprella tenuis	0.17	0.01	5.55	0.70	5.98	68.41

Note. SIMPER analysis comparison of Skilletfish (*Gobiesox strumosus*) diet similarity between Katrina and Legacy reefs. Average dissimilarity across reef groups was 92.87, group similarity within Katrina was 25.67, within group similarity for Legacy was 15.43.

Table 15

SIMPER Analysis Comparison of Skilletfish Diet Dissimilarity Between Katrina and Square Handkerchief Reefs

Species	**Katrina – average proportion**	**Square Handkerchief - average proportion**	**Average dissimilarity**	**Dissimilarity/ SD**	**Contribution %**	**Cumulative contribution**
Hourstonius laguna	0.47	0.07	15.89	1.24	17.27	17.27
Eurypanopeus depressus	0.06	0.20	7.51	0.55	8.17	25.44
Apocorophium louisianum	0.00	0.23	7.38	0.64	8.02	33.46
Unidentified xanthidae	0.11	0.11	6.18	0.69	6.72	40.18
Balanomorpha	0.12	0.06	6.09	0.46	6.62	46.80
Unidentified zoea	0.01	0.17	5.82	0.41	6.33	53.13
Paracaprella tenuis	0.17	0.00	5.43	0.68	5.90	59.03

Note. SIMPER analysis comparison of Skilletfish (*Gobiesox strumosus*) diet similarity between Katrina and Square Handkerchief reefs. Average dissimilarity across reef groups was 91.97, within group similarity for Katrina was 25.67, and within group similarity for Square Handkerchief was 9.52.

Table 16

SIMPER Analysis Comparison of Skilletfish Diet Dissimilarity Between Legacy and Square Handkerchief Reefs

Species	**Legacy - average proportion**	**Square Handkerchief - average proportion**	**Average dissimilarity**	**Dissimilarity/ SD**	**Contribution %**	**Cumulative contribution**
Eurypanopeus depressus	0.16	0.20	10.39	0.65	11.03	11.03
Neanthes succinea	0.27	0.04	9.80	0.63	10.40	21.43
Tegastidae	0.27	0.00	9.60	0.70	10.19	31.62
Xanthidae	0.17	0.11	8.29	0.68	8.80	40.42
Apocorophium louisianum	0.00	0.23	7.69	0.64	8.17	48.58
Unidentified zoea	0.00	0.17	5.69	0.37	6.04	54.63
Unidentified megalopae	0.11	0.05	5.11	0.48	5.42	60.05

Note. SIMPER analysis comparison of Skilletfish (*Gobiesox strumosus*) diet similarity between Legacy and Square Handkerchief reefs. Average dissimilarity across reef groups was 94.20, within Legacy group similarity was 15.43 and group similarity within Square Handkerchief was 9.52.

Table 17

SIMPER Analysis Comparison of Skilletfish Diet Dissimilarity Between Katrina and USM Reefs

Species	**Katrina - Average proportion**	**USM - average proportion**	**Average dissimilarity**	**Dissimilarity/ SD**	**Contribution %**	**Cumulative contribution**
Hourstonius laguna	0.47	0.01	15.37	1.26	16.72	16.72
Eurypanopeus depressus	0.06	0.27	8.77	0.71	9.54	26.26
Neanthes succinea	0.11	0.16	7.26	0.62	7.90	34.16
Balanomorpha	0.12	0.15	7.26	0.65	7.89	42.05
Unidentified xanthidae	0.11	0.15	6.69	0.69	7.27	49.32
Unidentified megalopae	0.13	0.12	6.35	0.75	6.91	56.23
Paracaprella tenuis	0.17	0.00	5.09	0.68	5.54	61.77

Note. SIMPER analysis comparison of Skilletfish (*Gobiesox strumosus*) diet similarity between Katrina and USM reefs. Average dissimilarity across reef groups was 91.94, group similarity was 25.67 within Katrina, and group similarity within USM was 16.67.

Table 18

SIMPER Analysis Comparison of Skilletfish Diet Dissimilarity Between Legacy and USM Reefs

Species	Legacy - Average proportion	USM - average proportion	Average dissimilarity	Dissimilarity/ SD	Contribution %	Cumulative contribution
Neanthes succinea	0.27	0.16	11.32	0.74	12.90	12.90
Eurypanopeus depressus	0.16	0.27	11.00	0.79	12.53	25.43
Unidentified tegastidae	0.27	0.07	8.85	0.74	10.08	35.51
Unidentifie xanthidae	0.17	0.15	8.64	0.71	9.84	45.35
Unidentified megalopae	0.11	0.12	6.27	0.57	7.15	52.50
Balanomorpha	0.00	0.15	4.67	0.49	5.32	57.82
Unidentified bryozoa	0.03	0.13	4.58	0.66	5.22	63.04

Note. SIMPER analysis comparison of Skilletfish (*Gobiesox strumosus*) diets between Legacy and USM reefs. Average dissimilarity across reef groups was 87.79, group similarity within Legacy was 15.43, and group similarity within USM was 16.67.

Table 19

SIMPER Analysis Comparison of Skilletfish Diet Dissimilarity Between Square Handkerchief and USM Reefs

Species	**Square Handkerchief - Average proportion**	**USM - average proportion**	**Average dissimilarity**	**Dissimilarity/ SD**	**Contribution %**	**Cumulative contribution**
Eurypanopeus depressus	0.20	0.27	11.64	0.79	12.72	12.72
Apocorophium louisianum	0.23	0.05	7.86	0.75	8.59	21.31
Xanthidae	0.11	0.15	7.17	0.66	7.84	29.14
Balanomorpha	0.06	0.15	6.28	0.50	6.86	36.00
Neanthes succinea	0.04	0.16	5.57	0.53	6.28	42.28
Unidentified zoea	0.17	0.00	5.29	0.37	5.78	48.06
Unidentified megalopae	0.05	0.12	4.82	0.60	5.27	53.33

Note. SIMPER analysis comparison of Skilletfish (*Gobiesox strumosus*) diets between Square Handkerchief and USM reefs. Average dissimilarity across reef groups was 91.52, group similarity within Square Handkerchief was 9.52, and group similarity within USM was 16.67.

Table 20

SIMPER Analysis Comparison of Skilletfish Diet Dissimilarity by Size Class

Species	**Large group - average proportion**	**Small group - average proportion**	**Average dissimilarity**	**Dissimilarity/ SD**	**Contribution %**	**Cumulative contribution**
Eurypanopeus depressus	0.16	0.22	10.85	0.74	11.76	11.76
Neanthes succinea	0.02	0.20	6.97	0.56	7.56	19.32
Unidentifie xanthidae	0.09	0.15	6.97	0.67	7.55	26.87
Unidentified bryozoa	0.19	0.03	6.62	0.84	7.17	34.04
Balanomorpha	0.14	0.06	6.09	0.44	6.60	40.64
Unidentifie tegastidae	0.00	0.15	5.37	0.52	5.82	46.45
Unidentified eggs	0.15	0.01	5.15	0.46	5.58	52.05

Note. SIMPER analysis comparison of Skilletfish (*Gobiesox strumosus*) diets by size class; between large and small size classes. Average dissimilarity across size groups was 92.26, group similarity within the large size class was 11.41, and within Small size class group similarity was 13.10.

Table 21

SIMPER Analysis Comparison of Skilletfish Diet Dissimilarity by Profile Type

Species	**High profile - average proportion**	**Low profile - average proportion**	**Average dissimilarity**	**Dissimilarity/ SD**	**Contribution %**	**Cumulative contribution**
Eurypanopeus depressus	0.15	0.23	10.20	0.71	11.04	11.04
Neanthes succinea	0.06	0.20	7.56	0.59	8.18	19.22
Unidentifie xanthidae	0.11	0.16	7.39	0.67	8.00	27.22
Hourstonius laguna	0.20	0.01	6.69	0.63	7.24	34.46
Apocorophium louisianum	0.16	0.04	5.63	0.58	6.10	40.56
Unidentified megalopae	0.08	0.12	5.44	0.59	5.89	52.22
Balanomorpha	0.08	0.10	5.33	0.45	5.77	57.23
Unidentified tegastidae	0.00	0.14	4.63	0.52	5.01	61.37

Note. SIMPER analysis comparison of Skilletfish (*Gobiesox strumosus*) diets by profile type. Average dissimilarity across profile groups was 92.37, within the High profile group similarity was 10.45, and within group similarity for the Low profile was 14.51.

Table 22

SIMPER Analysis Comparison of Skilletfish Diet Dissimilarity by Subregion

Species	**East - average proportion**	**West - average proportion**	**Average dissimilarity**	**Dissimilarity/ SD**	**Contribution %**	**Cumulative contribution**
Eurypanopeus depressus	0.14	0.25	10.22	0.73	11.34	11.34
Neanthes succinea	0.23	0.13	9.79	0.67	10.86	22.21
Unidentified xanthidae	0.15	0.14	8.04	0.69	8.92	32.12
Unidentifie tegastidae	0.21	0.05	7.17	0.63	7.95	39.07
Unidentified megalopae	0.12	0.10	6.00	0.58	6.65	45.72
Balanomorpha.	0.03	0.13	4.74	0.45	5.26	50.99
Hourstonius laguna	0.12	0.02	4.66	0.50	5.17	56.16
Unidentified bryozoa	0.03	0.10	3.63	0.56	4.02	60.19

Note. SIMPER analysis comparison of Skilletfish (*Gobiesox strumosus*) diets by subregion. Average dissimilarity across subregion groups was 90.13, group similarity within the eastern region was 12.83, and group similarity within the western region was 12.92.

MDS plots

MDS ordination compared diets of Skilletfish by reef, excluding fish diets which contained nothing, or all prey taxa were unidentified. All size classes of fish as shown in Figure 24 could not be easily interpreted due to the close proximity of the points, almost all were visually indiscernible except for four points.

Figure 24. MDS plot showing Bray-Curtis similarities of Skilletfish (*Gobiesox strumosus*) diets, plotted by reef for all three fish size classes combined, including all samples which were not empty or composed of entirely unidentified taxa.

Though these points were not excluded from any other analysis, MDS plots were more easily interpreted once two points were removed from the plot for clarity (Figure 25); however, most points remained in close proximity. Previous pairwise ANOSIM tests indicated significant differences between diets of small and larger size classes of Skilletfish, therefore, these were plotted separately (Figures 26 to 30) from the larger size classes (Figures 32 and 33), not including the points previously removed from the plots for clarity of scaling.

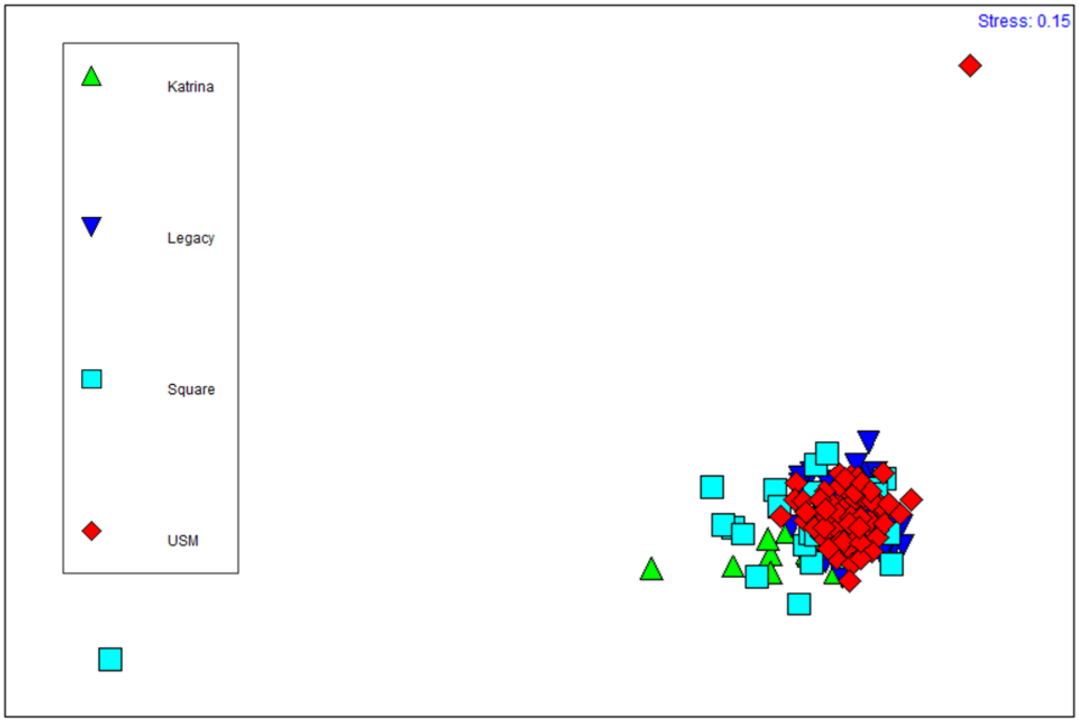


Figure 25. MDS plot showing Bray-Curtis similarities of Skilletfish (*Gobiesox strumosus*) diets, plotted by reef for all three fish size classes combined, less two data points removed for clarity of scaling.

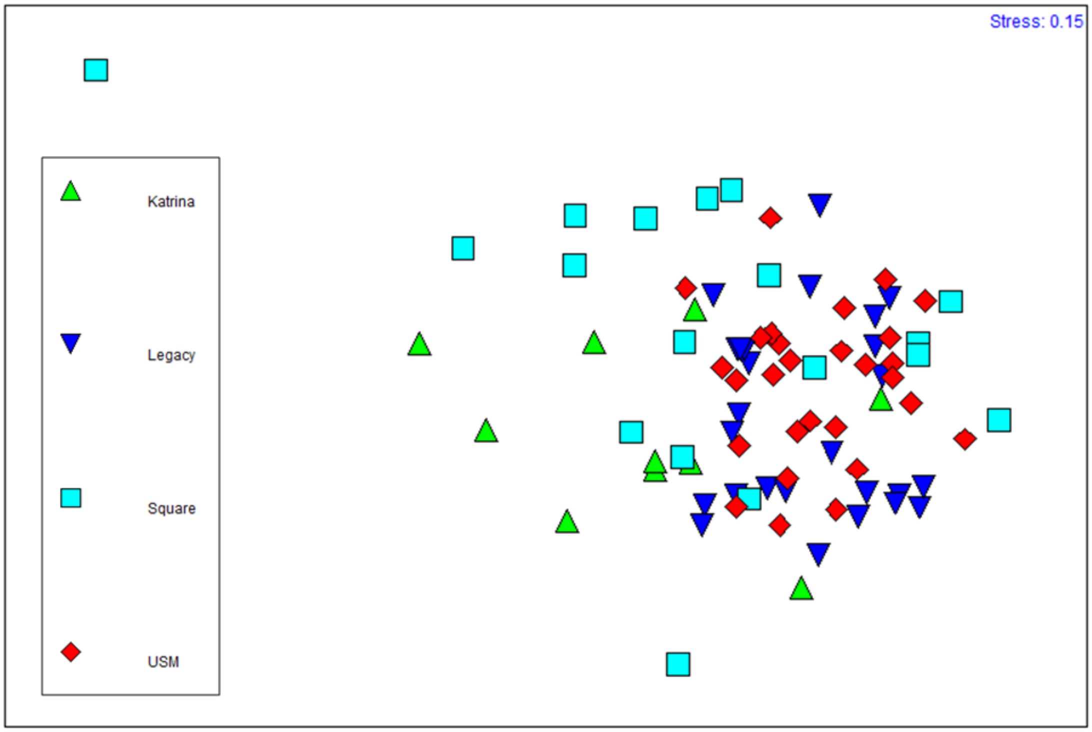


Figure 26. MDS plot showing Bray-Curtis similarities of Skilletfish (*Gobiesox strumosus*) diets, plotted by reef for small (<30 mm SL) size class fish only, less one data point removed for clarity of scaling.

Plotting small fish by reef allowed clearer interpretation; however, stress of the ordination was higher (0.15) after removal of one data point for clarity (Figure 26). Figure 26 shows marked diet non-overlap for both Katrina and Square Handkerchief reefs with each of the other reefs. When small fish diets are examined by reef type (Figure 27) there is a clearer degree of non-overlap, although stress of this ordination is again high (0.15). Considering small fish by subregion (Figure 28) in MDS gives a much less well defined differentiation of groups, with a high degree, but not complete overlap between the east and west subregions. Considering the medium and large size classes together, either by reef type (Figure 29) or by subregion (Figure 30), produces very similar MDS plots due to large numbers of medium and large fish from USM reef. Both the reef type plot and subregion plot suggest a small degree of non-overlap between groups with moderate stress (0.17) in both cases, however, little can be concluded from these plots due to low numbers of Skilletfish from eastern or high profile reef types in these size classes.

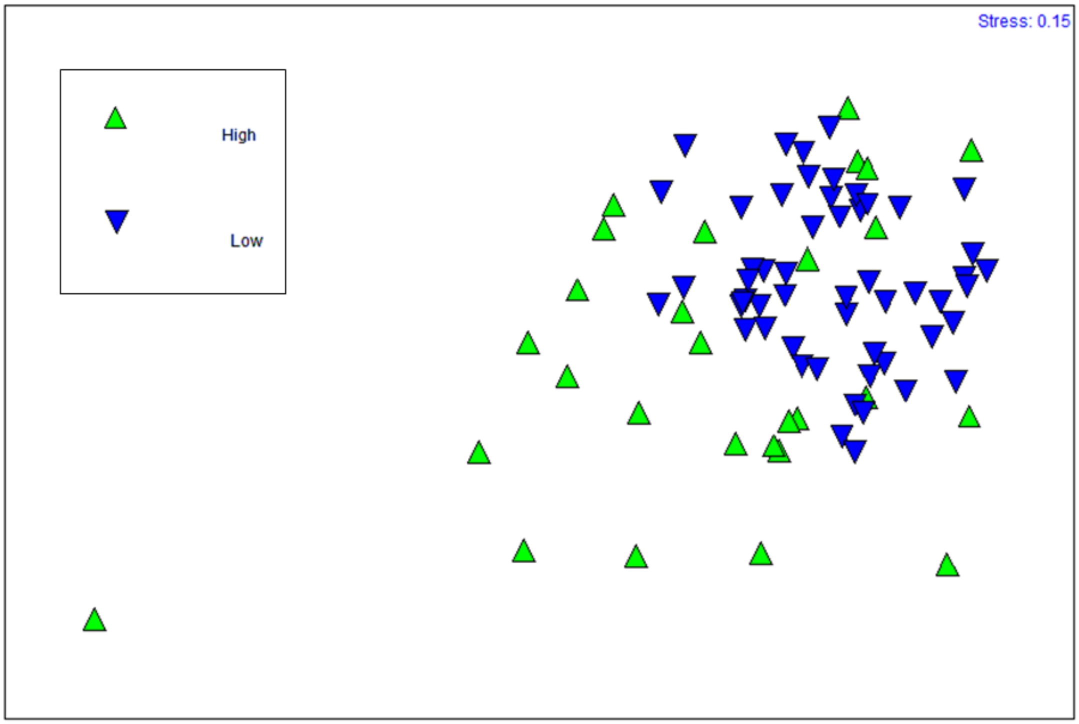


Figure 27. MDS plot showing Bray-Curtis similarities of Skilletfish (*Gobiesox strumosus*) diets, plotted by reef type for the small (<30 mm SL) size class fish only, less one data point due to scaling.

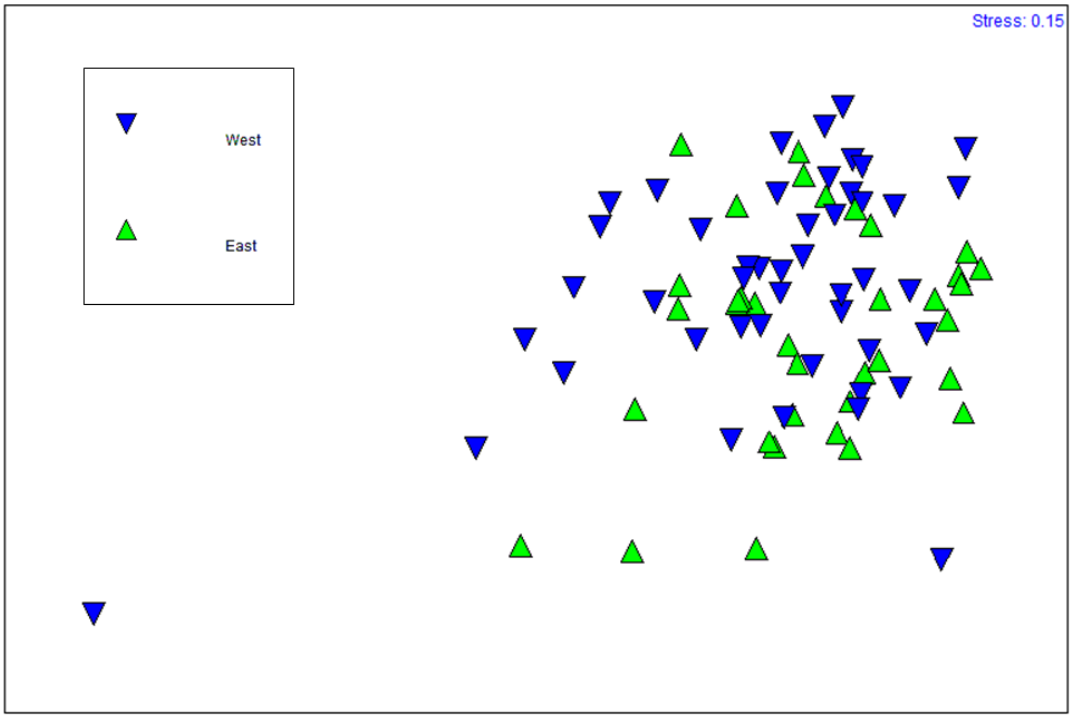


Figure 28. MDS plot showing Bray-Curtis similarities of Skilletfish (*Gobiesox strumosus*) diets, plotted by subregion for the small (<30 mm SL) size class only, less one data point due to scaling.

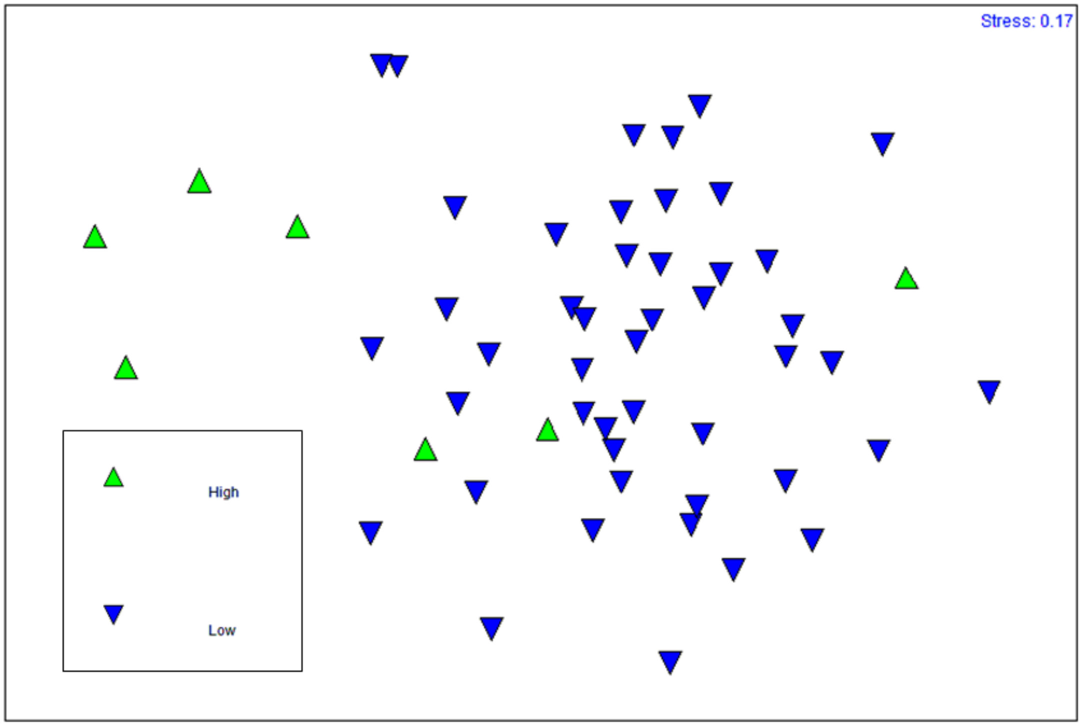


Figure 29. MDS plot showing Bray-Curtis similarities of Skilletfish (*Gobiesox strumosus*) diets, plotted by reef for both the medium (30 – 45 mm SL) and large (> 45 mm SL) fish size classes combined, less two data points due to scaling.

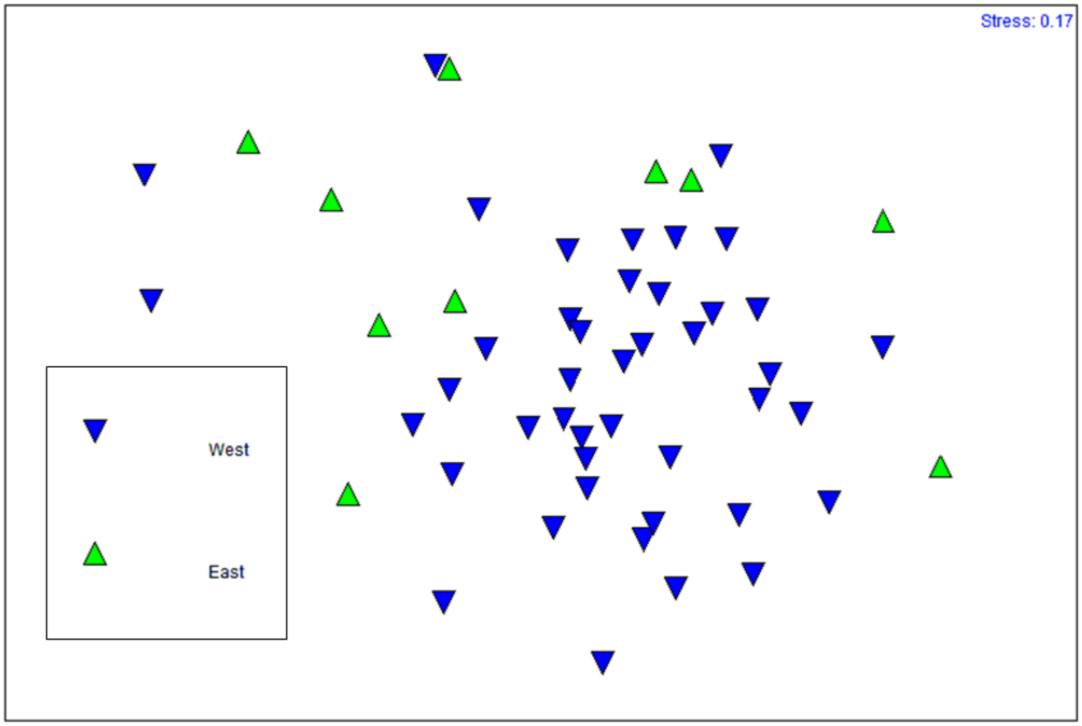


Figure 30. MDS plot showing Bray-Curtis similarities of Skilletfish (*Gobiesox strumosus*) diets, plotted by subregion, including medium (30 – 45 mm SL) and large (> 45 mm SL) fish size classes combined, less one data point due to scaling.

CHAPTER IV

DISCUSSION

Fish Catch and Composition

The high degree of variability observed in the numbers of fishes collected during this study, even within the same reefs and seasons, suggests a patchy distribution of resident reef fishes on the artificial reefs examined. Patchy fish distributions might correspond to the known patchy distribution of artificial reef substrata, and the proximity of samplers to patchy source habitat. This effect may have been further exacerbated by post-deployment movements of samplers away from such source habitats due to disturbance. Observed temporal differences in catch rates likely reflected seasonal differences in abundances or disturbance induced changes; for example, catch rates at USM reef during summer 2011 preliminary sampling were initially high, then dropped conspicuously low following a tropical storm during mid-summer 2011 at this shallow low profile site (personal observation).

Fish catches generally appeared higher on low profile reefs. Few studies are to be found in the literature considering small resident fishes on temperate reefs; however, Connell and Jones (1991) found a much greater density of the blennioid, *Forsterygion varium*, in reef habitats with complex structure, which was attributed to lower post-recruitment mortality. Hixon and Beets (1989) also reported higher densities of fish on artificial reefs with more refugia. The high complexity of the low profile oyster shell reefs in this study could provide more refuge habitat to resident fishes and thus increase fish survival and density. However, the conspicuousness of samplers on low profile reefs may have made them more attractive as habitat to resident benthic fishes than those set on high profile reef sites. Layman and Smith (2001) showed small marsh resident fishes used minnow traps as refuge habitat. *Fundulus heteroclitus* in laboratory experiments were able to move freely in and out of the trap when startled (Layman and Smith 2001), this suggests that fish may utilize minnow trap structure as habitat, especially where there are few alternatives.

The total footprint area of low profile reef sites was relatively small compared to high profile sites; estimated area was 2577 m^2 for Legacy, 4039 m^2 for USM, whereas the footprint area for the high profile reefs reached 14,566 m^2 for Katrina and 11,919 m^2 for Square Handkerchief. A number of studies have reported reef area as an important factor in fish utilization of artificial reefs (Bohnsack et al. 1994; Jordan et al. 2005; Schroeder 1987; Shulman 1985). For example, Bohnsack et al. (1994) reported fish densities were higher on small reefs, but biomass per unit area was greater on large reefs, as populations shifted towards larger, transient predatory fishes and small residents diminished (Bohnsack et al. 1994). Artificial reefs with high structural relief have also been shown to attract more benthic feeding fishes (Kellison and Sedbury 1998), which may also increase competition for benthic resources on high profile reefs. Thus, high profile reefs in this study may have attracted both higher densities of predatory fishes and more competition from larger fishes feeding on benthic invertebrates. With a greater total volume of reef material these conditions may act to reduce the density of benthic resident fishes. A lower density of benthic fishes would reduce the likelihood of fish encountering a trap, and also reduce competition for available refuge habitat on the reef, making the addition of the habitat provided by the samplers less attractive for colonization. Therefore, despite a large number of refugia, high density of resident fishes may make refuge habitat relatively scarce on low profile reefs, this may make both encounter rate and the likelihood of fishes utilizing sampler habitat higher. Either way, CPUE data might not accurately reflect differences in densities of resident fishes between reef types.

Catch per unit effort data obtained using minnow traps to estimate fish abundance has also been called into question, especially with increasing soak time, as fish can escape at unknown rates (Kneib and Craig 2001; Layman and Smith 2001). In addition, effects of gear selectivity were noted; marked differences were observed in species composition represented by the minnow trap and basket samplers during concurrent samples in the same location. Specifically the Featherduster Blenny occurred consistently in substrate basket samples, but was poorly represented or absent in concurrent minnow trap samples. This indicates differences in gear selectivity relative to this species.

Skilletfish Diets

The analysis of stomach contents of Skilletfish from this study is broadly in agreement with the limited information available for this species. Odum and Heald (1972) reported diets from Skilletfish collected from a Florida mangrove habitat to be dominated by amphipods, isopods, and chironomid larvae. Runyan (1961) reported only amphipods in a sample of 20 Skilletfish, but she also observed predation on fish and attempts to consume *Palaemonetes* in captivity. Hildebrand and Schroeder (1928) also reported Skilletfish diets collected from Chesapeake Bay contained isopods, amphipods, and annelids. More recently a stable isotope study by Abeels et al. (2012) including Skilletfish reported isotope ratios indicating diet sources dominated by microalgae, worms, and particulate organic matter. These results were based on a sample of eight fish collected from an oyster reef at the mouth of a creek in Estero Bay,FL.

Collectively these sources indicate a fairly broad diet which reflects the range of habitats in which Skilletfish may be found (Baltz et al. 1993; Modde and Ross 1980; Odum and Heald 1972; Runyan 1961) and is largely in agreement with the range of diet items found in this study. As previously reported, Skilletfish seem to be predominantly carnivorous; small arthropods appear to be important diet constituents, including gammaridean amphipods, corophiid amphipods, and harpacticoid copepods. As seen in the present study, small crabs can make up a very substantial part of the diet of Skilletfish. While Skilletfish have been noted as potential predators of crabs (Etherington et al. 2003), these results suggest xanthid crabs can make up about a quarter of the diet by volume in some locations.

Reef Type

Fish condition in four species could be compared between high and low profile reef types, of these only Naked Gobies did not show significantly poorer condition at high profile reefs. Gulf Toadfish, Feather Blennies and Skilletfish showed a pattern of significantly poorer condition in the high profile reef group. Even when considered as individual reefs, for no species was there significantly better condition on either high profile reef relative to either of the low profile reefs.

Similarly, significant patterns in Skilletfish diets were found when compared by reef type in terms of volume and composition. In keeping with the condition results for this species, diet volumes for Skilletfish were significantly larger on low profile reefs. The differences observed in fish condition, diet composition and diet volume when compared by reef profile may reflect a number of different characters of reef type. Defining the complexity of a habitat is difficult, but in this study, the low profile reef structure presumably provides a better match between the scaling of habitat complexity and the body size distribution of resident reef fishes than that of high profile reefs. A preference for matching of body size to shelter size by reef resident fishes has previously been demonstrated experimentally by Hixon and Beets (1989) using artificial reefs. Furthermore, Friedlander and Parrish (1998) reported distinct fish assemblage structures associated with discrete types of hard substrate habitat. The authors noted a strong relationship between the volume of available shelters in a habitat type and the length of fish occupying them. The low profile reef habitat with its numerous small interstices is scaled appropriately for small benthic resident fishes, such as Naked Gobies, Skilletfish, and Blennies, which can readily occupy small spaces between shells for use as refugia (Soniat et al. 2004) or for breeding habitat (Crabtree and Middaugh 1982), and can move through these small spaces to forage for food. Transient demersal reef-associated fishes, such as Pinfish and Sheepshead, are too large as adults to utilize the complex of numerous microhabitat spaces within the matrix of shell and limestone on low profile reefs. As such these larger species may only feed from the surfaces of the low profile reef material (Lindquist et al.1985). Conversely, the larger spaces between concrete blocks making up high profile reefs may be accessible to larger species of fish, including predators. These high profile interstices, while offering more protection than open water, may still provide much less protection to small resident fishes due to the mismatch in scaling (Eggleston et al. 1997; Hixon and Beets 1989). Additionally, the surface area provided by large pieces of rubble on high profile reefs may be much smaller by volume of material than that provided by low profile reef material. Increased surface area available for colonization could also foster a greater number of reef invertebrates as a source of food for resident fishes for a given volume of material. It is this large ratio of surface area to volume of substrate material in conjunction with the availability of appropriately scaled interstitial spaces on low profile reefs which presumably provides suitably scaled refugia matching the habitat preferences of small reef resident fishes.

A previous study examining the affects of reef complexity on a single species of blennioid fish, *F. varium*, suggests better growth in fish from highly complex reef habitats (Connell and Jones 1991) similar to low profile reefs in this study. As previously noted, high profile reefs in this study also had much greater foot print areas than low profile reefs. Large areas of reef (Bohnsack et al. 1994; Jordan et al. 2005; Schroeder 1987; Shulman 1985) and high relief reefs (Kellison and Sedbury 1998) have both been shown to attract more large, often predatory fishes compared to small, low profile reefs. Higher densities of predatory fishes on reefs may alter foraging behavior in resident fishes (Brown 1999; Dill 1983; Werner et al. 1983).

Presence of predators has been demonstrated to affect foraging behavior in other fishes (Kramer et al. 1983; Mittelbach 1981; Werner et al. 1983; Werner and Mittelbach 1981). For example, Werner et al. (1983) showed small Bluegill (*Lepomis macrochirus*) vulnerable to predation by Largemouth Bass (*Micropterus salmoides*) exhibited different habitat use compared to larger Bluegill that had reached a size refuge from Largemouth Bass predation. Small fishes tended to exploit habitat with more refuge even when little or no food was available in that habitat, but this difference in habitat use from larger Bluegill occurred only in the presence of the predator. Werner et al. (1983) also noted a significant depression in the growth of small size class of Bluegill in the presence of the predator. If the larger, high profile reefs do indeed attract more predatory fishes than the less prominent low profile reefs (Bohnsack et al.1994; Kellison and Sedbury 1998) then the poorer condition of high profile resident fishes noted in this study may partly be a consequence of predator avoidance reducing foraging time, or forcing resident fishes to utilize less lucrative habitat (Brown 1999; Dill 1983; Werner et al. 1983). Potential increases in the number of larger invertivorous fishes attracted to large, high profile reefs may also act to reduce availability of food to resident benthic fishes and therefore affect condition (Kellison and Sedbury 1998).

Distinct differences in diet volume for Skilletfish between reef types also showed fishes feeding on high profile reefs were not able to consume as much food as those on low profile reefs. This may support the assertion that small benthic fishes were unable to as effectively forage due predator avoidance behavior (Brown 1999; Dill 1983; Werner et al. 1983). Indeed, the lower structural complexity of habitat provided by high profile reefs may increase the likelihood of encounters with predators (Grabowski 2004; Grabowski and Powers 2004). However, disparity in diet volume may also reflect differences in foraging efficiency between reef types. High habitat complexity, as in the shell habitat of low profile reefs, allows high densities of intermediate predators to maintain foraging efficiency by reducing competition interference (Grabowski and Powers 2004)

Material Effects on Reef Residents

Reef invertebrates may be strongly affected by trophic interactions as mediated by the complexity of the type of reef. Grabowski (2004) showed that trophic cascade interactions between mud crabs, their predators the Oyster Toadfish, and their prey, juvenile oysters, were mediated by the complexity of their habitat. Oyster Toadfish predation in simple habitats controlled mud crabs and therefore limited predation on oysters. In complex habitats, however, Grabowski (2004) found a reduction in predation efficiency for both mud crabs and Oyster Toadfish. However, Grabowski and Powers (2004) further examined the effects of habitat complexity on foraging efficiency at different predator densities, and demonstrated that more complex habitats allow higher densities of predators by reducing interference competition between conspecifics, and therefore actually increase predator efficiency when predator densities were high relative to less complex habitats. Such differences in complexity between low and high profile reef structure in the present study may therefore explain some of the observed differences in fish condition. The more complex structure of oyster shell, compared to the simpler concrete block structure of high profile reefs, may facilitate higher densities of prey species and reduce interference between benthic fishes for food resources. Oyster shell may also lower the encounter rate between visiting predatory fishes and benthic resident fishes (Almany 2004), thus allowing more foraging time in what would otherwise be a more risky habitat (Brown 1999; Dill 1983; Newman 1991; Werner et al. 1983).

Skilletfish diet composition data suggest differences in prey taxa consumed between reef types, which may in turn affect fish condition. ANOSIM results suggest a weak but significant difference in diet composition by profile type. SIMPER results agreed, showing high dissimilarity between profile types, but low within group similarity. However, specific diet items were shown to drive differences in Skilletfish diets between reef types. This may be related to the specific preferences of some invertebrates for certain substrates. For example *N. succinea* has been shown to have a strong preference for oyster shell, particularly interstitial spaces within the shell matrix (Gutierrez et al.

2000). During this study *N. succinea* was a common diet item for Skilletfish.while occurring in samples from both reef types it was a much more common diet item on low profile reefs, suggesting reef type may have implications for either availability or accessibility of *N. succinea* by Skilletfish. Many sessile invertebrates also show strong preferences for settlement on, and significantly greater survival on specific substrates (Fitzhardinge and Bailey-Brock 1989; Nestlerode et al. 2007; Walters and Wethey 1996). For example, larval settlement by *C. virginica* is induced by chemical cues from both live adult oysters and biofilms on oyster shell material, both of which promote preferential gregarious settlement on oyster shell (Tamburri et al. 1992). Once metamorphosed, survival of oyster spat has also been shown to be higher on oyster shell than on other kinds of cultch material (Nestlerode et al. 2007) due to the availability of more suitable refugia from predators. While no availability data is presented here, differences in Skilletfish diet may also reflect differences in prevalence of prey taxa, and in turn this may also explain some differences in fish condition as the quality of prey items may differ by substrate type (Hyslop 1980; Pope et al. 2001). This question may be addressed in future work as the availability of invertebrate taxa on the artificial reefs sampled during this study was also assessed in a concurrent study, but data is not yet available.

The MDS ordinations of diet similarities show that diets of fish on high profile reefs encompass diets of fish on low profile reefs, particularly small size class fish. The cumulative numbers of prey taxa in fish diets on low profile reefs are higher on low profile reefs, suggesting a greater degree of specialization or selectivity on low profile reefs. Diet similarity, when compared between reef types had similar patterns, with higher similarity within low profile diets, suggesting fish were electing to consume more of the same prey taxa. A number of studies have shown a broadening in fish diets with a reduction in the availability of preferred prey taxa (Dill 1983; Dobel and Eggers 1978; Werner and Hall 1974), and a shift to less profitable prey which may also result in reduced growth (Galarowicz and Wahl 2005; Stahl and Stein 1994). Results of diet analysis in this study show a wider variety of prey taxa were present in Skilletfish diets on low profile than high profile reefs; however, higher within group similarities suggest many of these were exploited only occasionally. As noted by Dill (1983) switching to less preferable prey types would only be expected as an adaptive response to increased hunger. Therefore, lower diet volumes also support the suggestion that the high profile reef diets encompassing low profile diets may be the result of more limited availability of high quality prey items on high profile reefs. Thus, poorer condition in high profile Skilletfish may also be the result of a higher proportion of poorer quality prey taxa in high profile diets.

Subregion Effects

Subregional differences in the condition of cryptic fishes were significant effects for three of six species, each of which were in better condition from western reefs than from those in the eastern portion of Mississippi Sound. The condition patterns suggest possible corresponding variation in the quantity and or quality of food available to these species subregionally. A corresponding trend in the observed salinity gradient which decreased from east to west suggests abiotic and biotic factors might interact to influence the availability of certain food types. Distributions of a number of invertebrate reef residents have been shown to be strongly influenced by salinity, for example the crab *Panopeus herbstii,* is able to tolerate low salinity but occurs primarily at higher salinities

(Shumway 1983; Tolley et al. 2006) while the crab *Eurypanopeus depressus*, common in diets of Skilletfish in this study, has been shown to better tolerate low salinities by switching to osmosregulation below a salinity of 27 (Shirley and McKenney 1987; Wells 1961). Bottom salinity during the sampling period was only recorded to have exceeded 27 at Katrina reef during June and July. The ability to tolerate low salinity may give *E. depressus* a competitive advantage on reefs which experience a wide range of salinities (Dunson and Travis 1991) and this may explain higher volumes of *E. depressus* reported in diets from the lower salinity western subregion in this study.

Salinity may also influence the distribution and survival of oysters themselves. Inflow of freshwater has been shown to cause significant oyster mortality when salinity drops below 1 to 2 (La Peyre et al. 2003; May 1972). However, salinity also affects the distribution of the Southern oyster drill (*Stramonita haemastoma)* (Brown and Stickle 2002; Roller and Stickle 1989). Adult *S. haemastoma* are extremely tolerant of salinity stress, capable of survival down to 5‰, but feed only minimally at 7.5 ‰ (Garton and Stickle 1980). In the field they are rarely found below 15 ‰ (Garton and Stickle 1980), which also has dramatic consequences for the distribution of oysters, the principle prey species of the oyster drill. The influence of freshwater and predation pressure therefore act to limit the distribution of oysters.

Community Benefits of Oysters

The presence of oysters may also benefit small cryptic resident fishes as a food source. While this study did not sample diets of fish prior to settlement, larval Naked Gobies, Feather Blennies, and Striped Blennies have all been shown to preferentially consume oyster veligers (Harding 1999). Healthy oyster populations are therefore not only important to adult cryptic fishes as shelter and breeding substrate (Tolley and Voltey 2005), but also as a source of food for juvenile fishes, and therefore may influence survival and condition even prior to recruitment. The lower salinity conditions occurring at reefs in the western end of the Mississippi Sound may preclude heavy predation by oyster drills (Brown and Stickle 2002), and therefore indirectly benefit cryptic fish condition through various effects from oyster production. Presence of oysters may also benefit other reef residents, including xanthid crabs, which can be heavy consumers of oysters. Menzel and Nichy (1958) recorded an 80 mm stone crab (*Menippe mercenaria*) consumed an average of 26 50-60 mm oysters per week. As Gulf Toadfish diets have been shown to be dominated by xanthid crabs in a number of studies (Bisker et al. 1989; Grabowski 2004; Reid 1954; Springer and Woodburn 1960), the availability of oysters may indirectly promote the condition of this species. The poor condition of Gulf Toadfish collected from Katrina reef suggests the availability of appropriate prey items for this species was low at this reef.

Subregional Affects on Skilletfish Diets

Comparison of Skilletfish diets shows a weak but significant difference between east and west subregions of Mississippi Sound. A small degree of differentiation is apparent in MDS ordination, which appears to be driven largely by a larger proportion of mud crabs in western reef diets, with *N. succinea* and tegastid amphipods in the eastern reef diets. The mud crab has been shown to be extremely tolerant of a wide range of salinities to a leathal limit of 3 (Wells 1961) and may therefore be poor competitors in higher salinity conditions (Dunson and Travis 1991) such as those found at Katrina reef in the east. While no availability data is presented here, this ability to tolerate low salinity may account for the high proportion of Skilletfish diet made up by mud crabs on reefs with lower salinities, while this proportion falls in diets of Skilletfish from Katrina reef.

Wells (1961) reported *N. succinea* present over a wide range of salinities, but most numerous at an average of 18.98, similar to conditions in the eastern subregion in the present study. Little information is available in the literature on habitat preferences of tegastid amphipods, however, as they are closely associated with the epiphytal growth (Noodt 1971) and are found in the highest densities on substrates of high surface area (De Troch et al. 2005). If salinity gradients in the Mississippi Sound do not limit tegastid ampihpods in the western sound, lower available surface area, and, as indicated by Mazzei (2013), limited epiphytic growth with increasing depth on these high profile reef may do so.

Condition and Diet Variation by Reef

Notwithstanding the general pattern in fish condition relative to profile and subregion, there was no consistent pattern across species in terms of differences in condition among individual reefs. This suggests ecological factors responsible for variation in condition; such as the accessibility, and quantity and quality of available food may differ by species across reefs. Such individual differences may reflect species-specific diet preferences or abilities to obtain food items in similar habitats. For example, Skilletfish showed relatively good condition at Square Handkerchief reef; however, Freckled Blennies from this reef were in poorer condition than at other sites. This may reflect the exploitation of different food resources by these two species at Square Handkerchief reef. Lindquist and Dillaman (1986) describe Freckled Blennies diets to be dominated by algae and detritus, while the present study demonstrated Skilletfish consumed a wide variety of benthic invertebrates. Mazzei (2013) showed a significant decrease in both net productivity and Chlorophyll a concentrations with increasing depth while examining the reefs in this study. This suggests the greater habitat depths on high profile reefs may limit the availability of algae as a food source to Freckled Blennies, compared to low profile sites.

Reef type and subregional factors may also interact to affect reef residents differently across individual reefs (Brown and Stickle 2002; Roller and Stickle 1989) and in turn affect resident fish diet and condition on individual reefs. For example *N. succinea*, a common diet item for *G. strumosus* was most prevalent in low profile reef diets. High abundance of this species on low profile reefs may be related to this species habitat preference for internal shell cavities (Gutierrez et al. 2000). *Neanthes succinea* was also present in high profile reef diets, however as a proportion was extremely low in Square Handkerchief diets, in the western Sound subregion. When low profile reef diets are compared, a lower proportion is also apparent in USM diets, also in the western Sound. This subregional disparity in proportional diets may also reflect salinity preference in *N. succinea*, which Wells (1961) showed to favor brackish conditions in a similar range to those found at Katrina and Legacy reefs. Thus, differences in *G. strumosus* may reflect both reef and subregional differences.

Differences in invertebrate colonization and survival based on the suitability of reef material in interaction with suitability of subregional abiotic conditions may in turn have consequences for biotic interactions with the species to which they provide habitat or food. Predator prey interactions, also mediated by reef habitat complexity may determine forage efficiency for intermediate predators including resident fishes. In turn, lucrative foraging, where predator evasion and reproductive success allow, results in dense resident fish populations with high condition factors. Choices made in artificial reef materials, design, and location may have a strong influence on the secondary productivity of the resident community which develops. Differences in reef secondary productivity may be strongly indicated in the production of resident benthic fishes that may also provide an important trophic link to transient fishes. Transient fish production is often the ultimate goal of artificial reef projects, however, establishing a link between productivity in these species and reefs themselves has thus far proved difficult to achieve. Measuring productivity in resident benthic fishes may therefore be an achievable approach to this end.

APPENDIX A

SIMILARITY PERCENTAGES (SIMPER) OUTPUT

SIMPER results based on arcsine square root transformed proportional diet volume Bray-Curtis similiarities of Skilletfish (*Gobiesox strumosus*) diet taxa. Diet taxa are compared for within group similarity, for the East sub-region reefs, Katrina and Legacy. Contributions of taxa are listed in descending order of percentage contribution to total within group similarity. Taxa above 90% cumulative contribution are not included. Group average similarity is 12.83.

Species	**Average Abundance**	**Average Similarity**	**Similarity /SD**	**Contribution %**	**Cum.%**
Unidentified tegastidae	0.21	3.29	0.38	25.66	25.66
Neanthes succinea	0.23	3.04	0.27	23.68	49.34
Unidentified xanthid	0.15	1.83	0.22	14.23	63.57
Hourstonius laguna	0.12	1.22	0.18	9.48	73.05
Eurypanopeus depressus	0.14	1.11	0.15	8.68	81.73
Unidentified megalopa	0.12	0.9	0.19	7.05	88.78
Unidentified harpcaticoid	0.07	0.58	0.22	4.53	93.31

SIMPER results based on arcsine square root transformed proportional diet volume Bray-Curtis similiarities of Skilletfish (*Gobiesox strumosus*) diet taxa. Diet taxa are compared for within group similarity, for the West sub-region reefs USM and Square Handkerchief. Contributions of taxa are listed in descending order of percentage contribution to total within group similarity. Taxa above 90% cumulative contribution are not included. Group average similarity is 12.92.

Species	**Average. Abundance**	**Average. Similarity**	**Similarity /SD**	**Contribution %**	**Cum.%**
Eurypanopeus depressus	0.25	3.31	0.32	25.62	25.62
Unidentified xanthid	0.14	1.62	0.27	12.57	38.19
Unidentified megalopa	0.10	1.09	0.25	8.42	46.61
Unidentified bryozoa	0.10	0.97	0.24	7.54	54.15

(continued).

Species	**Average. Abundance**	**Average. Similarity**	**Similarity /SD**	**Contribution %**	**Cum.%**
Neanthes succinea	0.13	0.93	0.18	7.23	61.38
Apocorophium louisianum	0.10	0.91	0.22	7.06	68.44
Balanomorpha	0.13	0.89	0.18	6.86	75.3
Unidentified ostracoda	0.06	0.64	0.28	4.99	80.29
Unidentified tegastidae	0.05	0.61	0.27	4.72	85.01
Unidentified eggs	0.08	0.58	0.19	4.50	89.51
Unidentified fish	0.05	0.34	0.19	2.64	92.15

SIMPER results based on arcsine square root transformed proportional diet volume Bray-Curtis similiarities of Skilletfish (*Gobiesox strumosus*) diet taxa. Diet taxa are compared by sub-region for between group dissimilarity. Contributions of taxa are listed in descending order of percentage contribution to total within group similarity. Taxa above 90% cumulative contribution are not included. Average dissimilarity was 90.13.

Species	**Average Abundance East**	**Average Abundance West**	**Average Dissimilarity**	**Dissimilarity /SD**	**Contribution %**	**Cum.%**
Eurypanopeus depressus	0.14	0.25	10.22	0.73	11.34	11.34
Neanthes succinea	0.23	0.13	9.79	0.67	10.86	22.21
Unidentified xanthid	0.15	0.14	8.04	0.69	8.92	31.12
Unidentified tegastidae	0.21	0.05	7.17	0.63	7.95	39.07
Unidentified megalopa	0.12	0.10	6.00	0.58	6.65	45.72
Balanomorpha	0.03	0.13	4.74	0.45	5.26	50.99
Hourstonius laguna	0.12	0.02	4.66	0.50	5.17	56.16
Unidentified bryozoa	0.03	0.10	3.63	0.56	4.02	60.19
Apocorophium louisianum	0.00	0.10	3.31	0.45	3.67	63.85

(continued).

Species	Average Abundance East	Average Abundance West	Average Dissimilarity	Dissimilarity /SD	Contribution %	Cum.%
Unidentified harpcaticoid	0.07	0.03	2.86	0.56	3.18	67.03
Palaemontes pugio	0.05	0.04	2.66	0.29	2.95	69.98
Unidentified eggs	0.00	0.08	2.58	0.37	2.86	72.84
Unidentified ostracoda	0.01	0.06	2.18	0.50	2.42	75.25
Unidentified arthropoda	0.04	0.03	2.13	0.33	2.36	77.61
Unidentified zoea	0.00	0.04	1.63	0.20	1.81	79.42
Unidentified fish	0.01	0.05	1.59	0.43	1.77	81.18
Paracaprella tenuis	0.05	0.00	1.50	0.33	1.67	82.85
Balanus improvisus	0.00	0.04	1.31	0.19	1.46	84.31
Polydora spp.	0.02	0.03	1.28	0.41	1.42	85.73
Monocorophium acherusicum	0.03	0.01	1.13	0.32	1.26	86.99
Unidentified bivalve	0.02	0.01	1.05	0.35	1.16	88.15
Crassostrea virginica	0.03	0.00	0.93	0.33	1.03	89.18
Penaeus setiferus	0.03	0.00	0.92	0.14	1.03	90.21

SIMPER results based on arcsine square root transformed proportional diet volume Bray-Curtis similiarities of Skilletfish (*Gobiesox strumosus*) diet taxa. Diet taxa are compared for within group similarity, for the High profile group. Contributions of taxa are listed in descending order of percentage contribution to total within group similarity. Taxa above 90% cumulative contribution are not included. Group average similarity is 10.45.

Species	Average Abundance	Average Similarity	Similarity/SD	Contribution %	Cum.%
Hourstonius laguna	0.20	3.29	0.31	31.47	31.47
Apocorophium louisianum	0.16	1.50	0.20	14.40	45.87
Unidentified xanthid	0.11	1.10	0.19	10.52	56.39

(continued).

Species	**Average Abundance**	**Average Similarity**	**Similarity/SD**	**Contribution %**	**Cum.%**
Eurypanopeus depressus	0.15	1.06	0.14	10.11	66.50
Unidentified megalopa	0.08	0.73	0.17	7.00	73.50
Unidentified arthropoda	0.11	0.68	0.15	6.52	80.02
Unidentified zoea	0.12	0.46	0.09	4.36	84.38
Neanthes succinea	0.06	0.26	0.12	2.45	86.83
Unidentified corophium	0.04	0.25	0.09	2.38	89.21
Paracaprella tenuis	0.06	0.23	0.09	2.21	91.41

SIMPER results based on arcsine square root transformed proportional diet volume Bray-Curtis similiarities of Skilletfish (*Gobiesox strumosus*) diet taxa. Diet taxa are compared for within group similarity, for the Low profile group. Contributions of taxa are listed in descending order of percentage contribution to total within group similarity. Taxa above 90% cumulative contribution are not included. Group average similarity is 14.51.

Species	**Average Abundance**	**Average Similarity**	**Similarity/SD**	**Contribution %**	**Cum.%**
Eurypanopeus depressus	0.23	3.09	0.31	21.29	21.29
Neanthes succinea	0.20	2.23	0.25	15.35	36.65
Unidentified tegastidae	0.14	2.15	0.39	14.84	51.49
Unidentified xanthid	0.16	1.88	0.27	12.99	64.48
Unidentified megalopa	0.12	1.14	0.25	7.88	72.36
Unidentified bryozoa	0.10	0.96	0.24	6.63	79.00
Balanomorpha	0.10	0.61	0.16	4.19	83.18
Unidentified harpcaticoid	0.05	0.55	0.26	3.81	86.99
Unidentified ostracoda	0.05	0.45	0.25	3.10	90.09

SIMPER results based on arcsine square root transformed proportional diet volume Bray-Curtis similiarities of *Skilletfish* (*Gobiesox strumosus*) diet taxa. Diet taxa are compared by reef type for between group dissimilarity. Contributions of taxa are listed in descending order of percentage contribution to total within group similarity. Taxa above 90% cumulative contribution are not included. Average dissimilarity was 92.37.

Species	**Average Abundance High**	**Average Abundance Low**	**Average Dissimilarity**	**Dissimilarity/SD**	**Contribution %**	**Cum.%**
Eurypanopeus depressus	0.15	0.23	10.20	0.71	11.04	11.04
Neanthes succinea	0.06	0.20	7.56	0.59	8.18	19.22
Unidentified xanthid	0.11	0.16	7.39	0.67	8.00	27.22
Hourstonius laguna	0.20	0.01	6.69	0.63	7.24	34.46
Apocorophium louisianum	0.16	0.04	5.63	0.58	6.10	40.56
Unidentified megalopa	0.08	0.23	5.44	0.59	5.89	46.45
Balanomorpha	0.08	0.10	5.33	0.45	5.77	52.22
Unidentified tegastidae	0.00	0.14	4.63	0.52	5.01	57.23
Unidentified zoea	0.12	0.00	3.82	0.31	4.14	61.37
Unidentified arthropoda	0.11	0.01	3.53	0.41	3.82	65.19
Unidentified bryozoa	0.02	0.10	3.36	0.53	3.64	68.83
Unidentified eggs	0.02	0.07	2.49	0.38	2.70	71.52
Unidentified harpcaticoid	0.02	0.05	2.32	0.53	2.51	74.03
Unidentified ostracoda	0.03	0.05	2.27	0.52	2.46	76.49
Unidentified fish	0.03	0.03	1.90	0.43	2.06	78.55
Unidentified corophium	0.04	0.00	1.84	0.31	2.00	80.55
Palaemontes pugio	0.00	0.06	1.83	0.24	1.98	82.53
Paracaprella tenuis	0.06	0.00	1.76	0.35	1.91	84.44
Apocorophium lacustre	0.05	0.00	1.67	0.26	1.81	86.25
Leptochelia rapax	0.04	0.01	1.64	0.19	1.78	88.03

(continued).

Species	**Average Abundance High**	**Average Abundance Low**	**Average Dissimilarity**	**Dissimilarity/SD**	**Contribution %**	**Cum.%**
Unidentified bivalve	0.04	0.01	1.32	0.37	1.43	89.46
Balanus improvisus	0.00	0.04	1.18	0.18	1.27	90.74

SIMPER results based on arcsine square root transformed proportional diet volume Bray-Curtis similiarities of Skilletfish (*Gobiesox strumosus*) diet taxa. Diet taxa are compared for within group similarity for Katrina reef. Contributions of taxa are listed in descending order of percentage contribution to total within group similarity. Taxa above 90% cumulative contribution are not included. Group average similarity is 25.67.

Species	**Average Abundance**	**Average Similarity**	**Similarity/SD**	**Contribution %**	**Cum.%**
Hourstonius laguna	0.47	18.30	0.86	71.28	71.28
Paracaprella tenuis	0.17	2.33	0.31	9.06	80.34
Unidentified megalopa	0.13	1.38	0.22	5.39	85.74
Unidentified arthropoda	0.11	1.08	0.22	4.20	89.94
Unidentified xanthid	0.11	0.78	0.20	3.05	92.99

SIMPER results based on arcsine square root transformed proportional diet volume Bray-Curtis similiarities of Skilletfish (*Gobiesox strumosus*) diet taxa. Diet taxa are compared for within group similarity for Legacy reef. Contributions of taxa are listed in descending order of percentage contribution to total within group similarity. Taxa above 90% cumulative contribution are not included. Group average similarity is 15.43.

Species	**Average Abundance**	**Average Similarity**	**Similarity/SD**	**Contribution %**	**Cum.%**
Unidentified tegastidae	0.27	5.70	0.51	36.92	36.92

(continued).

Species	Average Abundance	Average Similarity	Similarity/SD	Contribution %	Cum.%
Neanthes succinea	0.27	4.08	0.31	26.46	63.38
Unidentified xanthid	0.17	2.10	0.22	13.63	77.01
Eurypanopeus depressus	0.16	1.53	0.18	9.94	86.95
Unidentified harpcaticoid	0.08	0.78	0.24	5.08	92.03

SIMPER results based on arcsine square root transformed proportional diet volume Bray-Curtis similiarities of Skilletfish (*Gobiesox strumosus*) diet taxa. Diet taxa are compared for within group similarity for Square Handkerchief reef. Contributions of taxa are listed in descending order of percentage contribution to total within group similarity. Taxa above 90% cumulative contribution are not included. Group average similarity is 9.52.

Species	Average Abundance	Average Similarity	Similarity/SD	Contribution %	Cum.%
Apocorophium louisianum	0.23	3.34	0.30	35.09	35.09
Eurypanopeus depressus	0.20	1.66	0.18	17.43	52.52
Unidentified xanthid	0.11	1.04	0.18	10.98	63.50
Unidentified zoea	0.17	0.84	0.12	8.87	72.37
Unidentified corophium	0.06	0.46	0.12	4.79	77.16

SIMPER results based on arcsine square root transformed proportional diet volume Bray-Curtis similiarities of Skilletfish (*Gobiesox strumosus*) diet taxa. Diet taxa are compared for within group similarity for USM reef. Contributions of taxa are listed in descending order of percentage contribution to total within group similarity. Taxa above 90% cumulative contribution are not included. Group average similarity is 16.67.

Species	Average Abundance	Average Similarity	Similarity/SD	Contribution %	Cum.%
Eurypanopeus depressus	0.27	3.95	0.38	23.71	23.71

(continued).

Species	**Average Abundance**	**Average Similarity**	**Similarity/SD**	**Contribution %**	**Cum.%**
Unidentified xanthid	0.15	1.80	0.31	10.78	34.49
Unidentified bryozoa	0.13	1.66	0.32	9.94	44.43
Balanomorpha	0.15	1.40	0.24	8.41	52.84
Neanthes succinea	0.16	1.39	0.21	8.34	61.18
Unidentified megalopa	0.12	1.35	0.30	8.09	69.27
Unidentified tegastidae	0.07	1.14	0.38	6.87	76.14
Unidentified ostracoda	0.07	0.97	0.37	5.81	81.95
Unidentified eggs	0.10	0.83	0.22	4.95	86.90
Apocorophium louisianum	0.05	0.53	0.24	3.21	90.11

SIMPER results based on arcsine square root transformed proportional diet volume Bray-Curtis similiarities of Skilletfish (*Gobiesox strumosus*) diet taxa. Diet taxa are compared by profile type for between group dissimilarity. Contributions of taxa are listed in descending order of percentage contribution to total within group similarity. Taxa above 90% cumulative contribution are not included. Average dissimilarity was 92.87.

Species	**Average Abundance Katrina**	**Average Abundance Legacy**	**Average Dissimilarity**	**Dissimilarity/SD**	**Contribution %**	**Cum.%**
Hourstonius laguna	0.47	0.01	16.65	1.26	17.93	17.93
Neanthes succinea	0.11	0.27	10.80	0.72	11.63	29.56
Unidentified tegastidae	0.01	0.27	9.18	0.71	9.88	39.44
Unidentified xanthid	0.11	0.17	7.75	0.71	8.35	47.79
Unidentified megalopa	0.13	0.11	6.87	0.64	7.40	55.20
Eurypanopeus depressus	0.06	0.16	6.73	0.55	7.24	62.44
Paracaprella tenuis	0.17	0.01	5.55	0.70	5.98	68.41

(continued).

Species	**Average Abundance Katrina**	**Average Abundance Legacy**	**Average Dissimilarity**	**Dissimilarity/SD**	**Contribution %**	**Cum.%**
Balanomorpha	0.12	0.00	4.39	0.42	4.73	73.14
Unidentified arthropoda	0.11	0.01	3.95	0.59	4.25	77.39
Unidentified harpcaticoid	0.02	0.08	3.07	0.55	3.30	80.69
Unidentified bivalve	0.05	0.01	2.06	0.57	2.21	82.91
Palaemontes pugio	0.00	0.07	2.04	0.24	2.20	85.11
Monocorophium acherusicum	0.04	0.02	1.95	0.40	2.10	87.21
Unidentified ostracoda	0.04	0.00	1.38	0.43	1.49	88.69
Penaeus setiferus	0.00	0.04	1.26	0.17	1.36	90.05

SIMPER results based on arcsine square root transformed proportional diet volume Bray-Curtis similiarities of Skilletfish (*Gobiesox strumosus*) diet taxa. Diet taxa are compared by profile type for between group dissimilarity. Contributions of taxa are listed in descending order of percentage contribution to total within group similarity. Taxa above 90% cumulative contribution are not included. Average dissimilarity was 91.97

Species	**Average Abundance Katrina**	**Average Abundance Sq. Hand**	**Average Dissimilarity**	**Dissimilarity/SD**	**Contribution %**	**Cum.%**
Hourstonius laguna	0.47	0.07	15.89	1.24	17.27	17.27
Eurypanopeus depressus	0.06	0.20	7.51	0.55	8.17	25.44
Apocorophium louisianum	0.00	0.23	7.38	0.64	8.02	33.46
Unidentified arthropoda	0.11	0.10	6.18	0.63	6.72	40.18
Unidentified xanthid	0.11	0.11	6.18	0.69	6.72	46.90
Balanomorpha	0.12	0.06	6.09	0.46	6.62	53.53
Unidentified zoea	0.01	0.17	5.82	0.41	6.33	59.86

(continued).

Species	**Average Abundance Katrina**	**Average Abundance Sq. Hand**	**Average Dissimilarity**	**Dissimilarity/SD**	**Contribution %**	**Cum.%**
Paracaprella tenuis	0.17	0.00	5.43	0.68	5.90	65.76
Unidentified megalopa	0.13	0.05	5.39	0.69	5.87	71.63
Neanthes succinea	0.11	0.04	4.49	0.50	4.88	76.51
Unidentified corophium	0.01	0.06	2.70	0.40	2.93	79.44
Apocorophium lacustre	0.00	0.08	2.43	0.31	2.63	82.08
Unidentified bivalve	0.05	0.03	2.42	0.56	2.63	84.71
Leptochelia rapax	0.00	0.06	2.05	0.20	2.23	86.93
Unidentified ostracoda	0.04	0.02	1.96	0.49	2.13	89.07
Melita spp.	0.00	0.04	1.57	0.33	1.71	90.78

SIMPER results based on arcsine square root transformed proportional diet volume Bray-Curtis similiarities of Skilletfish (*Gobiesox strumosus*) diet taxa. Diet taxa are compared by profile type for between group dissimilarity. Contributions of taxa are listed in descending order of percentage contribution to total within group similarity. Taxa above 90% cumulative contribution are not included. Average dissimilarity was 94.20.

Species	**Average Abundance Legacy**	**Average Abundance Sq Hand**	**Average Dissimilarity**	**Dissimilarity/SD**	**Contribution %**	**Cum.%**
Eurypanopeus depressus	0.16	0.20	10.39	0.65	11.03	11.03
Neanthes succinea	0.27	0.04	9.80	0.63	10.40	21.43
Unidentified tegastidae	0.27	0.00	9.60	0.70	10.19	31.62
Unidentified xanthid	0.17	0.11	8.29	0.68	8.80	40.42
Apocorophium louisianum	0.00	0.23	7.69	0.64	8.17	48.59
Unidentified zoea	0.00	0.17	5.69	0.37	6.04	54.63

(continued).

Species	**Average Abundance Legacy**	**Average Abundance Sq Hand**	**Average Dissimilarity**	**Dissimilarity/SD**	**Contribution %**	**Cum.%**
Unidentified megalopa	0.11	0.05	5.11	0.48	5.42	60.05
Unidentified arthropoda	0.01	0.10	3.87	0.39	4.11	64.16
Unidentified harpcaticoid	0.08	0.02	3.35	0.53	3.56	67.72
Unidentified corophium	0.01	0.06	2.80	0.37	2.98	70.70
Apocorophium lacustre	0.00	0.08	2.51	0.31	2.67	73.36
Hourstonius laguna	0.01	0.07	2.37	0.41	2.52	75.89
Leptochelia rapax	0.00	0.06	2.13	0.20	2.26	78.15
Balanomorpha	0.00	0.06	2.13	0.20	2.26	80.41
Palaemontes pugio	0.07	0.00	2.11	0.24	2.24	82.65
Unidentified fish	0.01	0.05	1.77	0.34	1.88	84.53
Unidentified bryozoa	0.03	0.03	1.77	0.36	1.88	86.40
Melita spp.	0.00	0.04	1.66	0.32	1.76	88.17
Penaeus setiferus	0.04	0.00	1.30	0.17	1.38	89.55
Unidentified bivalve	0.01	0.03	1.28	0.32	1.36	90.91

SIMPER results based on arcsine square root transformed proportional diet volume Bray-Curtis similiarities of Skilletfish (*Gobiesox strumosus*) diet taxa. Diet taxa are compared by profile type for between group dissimilarity. Contributions of taxa are listed in descending order of percentage contribution to total within group similarity. Taxa above 90% cumulative contribution are not included. Average dissimilarity was 91.94

Species	**Average Abundance Katrina**	**Average Abundance USM**	**Average Dissimilarity**	**Dissimilarity/SD**	**Contribution %**	**Cum.%**
Hourstonius laguna	0.47	0.01	15.37	1.26	16.72	16.72

(continued).

Species	**Average Abundance Katrina**	**Average Abundance USM**	**Average Dissimilarity**	**Dissimilarity/SD**	**Contribution %**	**Cum.%**
Eurypanopeus depressus	0.06	0.27	8.77	0.71	9.54	26.26
Neanthes succinea	0.11	0.16	7.26	0.62	7.90	34.16
Balanomorpha	0.12	0.15	7.26	0.65	7.89	42.05
Unidentified xanthid	0.11	0.15	6.69	0.69	7.27	49.32
Unidentified megalopa	0.13	0.12	6.35	0.75	6.91	56.23
Paracaprella tenuis	0.17	0.00	5.09	0.68	5.54	61.77
Unidentified bryozoa	0.00	0.13	3.90	0.60	4.24	66.02
Unidentified arthropoda	0.11	0.00	3.45	0.57	3.76	69.77
Unidentified eggs	0.00	0.10	3.14	0.41	3.41	73.18
Unidentified ostracoda	0.04	0.07	2.96	0.65	3.22	76.41
Unidentified tegastidae	0.01	0.07	2.16	0.74	2.35	78.75
Balanus improvisus	0.00	0.05	1.74	0.23	1.89	80.65
Unidentified bivalve	0.05	0.01	1.74	0.56	1.89	82.54
Monocorophium acherusicum	0.04	0.02	1.69	0.35	1.84	84.38
Palaemontes pugio	0.00	0.06	1.67	0.24	1.82	86.19
Unidentified harpcaticoid	0.02	0.04	1.66	0.68	1.81	88.00
Apocorophium louisianum	0.00	0.05	1.65	0.51	1.80	89.80
Unidentified fish	0.00	0.05	1.39	0.49	1.52	91.32

SIMPER results based on arcsine square root transformed proportional diet volume Bray-Curtis similiarities of Skilletfish (*Gobiesox strumosus*) diet taxa. Diet taxa are compared by profile type for between group dissimilarity. Contributions of taxa are listed in descending order of percentage contribution to total within group similarity. Taxa above 90% cumulative contribution are not included. Average dissimilarity was 87.79.

Species	**Average Abundance Legacy**	**Average Abundance USM**	**Average Dissimilarity**	**Dissimilarity/SD**	**Contribution %**	**Cum.%**
Neathes succinea	0.27	0.16	11.32	0.74	12.90	12.90
Eurypanopeus depressus	0.16	0.27	11.00	0.79	12.53	25.43
Unidentified tegastidae	0.27	0.07	8.85	0.74	10.08	35.51
Unidentified xanthid	0.17	0.15	8.64	0.71	9.84	45.35
Unidentified megalopa	0.11	0.12	6.27	0.57	7.15	52.50
Balanomorpha	0.00	0.15	4.58	0.49	5.32	57.82
Unidentified bryozoa	0.03	0.13	3.58	0.66	5.22	63.04
Palaemontes pugio	0.07	0.06	3.53	0.34	4.02	67.07
Unidentified harpcaticoid	0.08	0.04	3.27	0.60	3.72	70.79
Unidentified eggs	0.00	0.10	3.26	0.40	3.71	74.50
Unidentified ostracoda	0.00	0.07	2.38	0.52	2.71	77.22
Balanus improvisus	0.00	0.05	1.81	0.23	2.07	79.28
Apocorophium louisianum	0.00	0.05	1.75	0.52	1.99	81.27
Polydora spp.	0.02	0.04	1.70	0.49	1.94	83.21
Unidentified fish	0.01	0.05	1.60	0.53	1.83	85.03
Crassostrea virginica	0.04	0.00	1.23	0.39	1.40	86.43
Penaeus setiferus	0.04	0.00	1.22	0.17	1.39	87.82
Monocorophium acherusicum	0.02	0.02	1.07	0.34	1.22	89.04
Apocorophium spp.	0.00	0.03	1.06	0.16	1.21	90.25

SIMPER results based on arcsine square root transformed proportional diet volume Bray-Curtis similiarities of Skilletfish (*Gobiesox strumosus*) diet taxa. Diet taxa are compared by profile type for between group dissimilarity. Contributions of taxa are listed in descending order of percentage contribution to total within group similarity. Taxa above 90% cumulative contribution are not included. Average dissimilarity was 91.52.

Species	**Average Abundance Sq. Hand**	**Average Abundance USM**	**Average Dissimilarity**	**Dissimilarity/SD**	**Contribution %**	**Cum.%**
Eurypanopeus depressus	0.20	0.27	11.64	0.79	12.72	12.72
Apocorophium louisianum	0.23	0.05	7.86	0.75	8.59	21.31
Unidentified xanthid	0.11	0.15	7.17	0.66	7.84	29.14
Balanomorpha	0.06	0.15	6.28	0.50	6.86	36.00
Neathes succinea	0.04	0.16	5.72	0.53	6.28	42.28
Unidentified zoea	0.17	0.00	5.29	0.37	5.78	48.06
Unidentified megalopa	0.05	0.12	4.82	0.60	5.27	53.33
Unidentified bryozoa	0.03	0.13	4.49	0.63	4.91	58.24
Unidentified eggs	0.02	0.10	3.66	0.46	4.00	62.24
Unidentified arthropoda	0.10	0.00	3.28	0.36	3.59	65.83
Unidentified ostracoda	0.02	0.07	2.84	0.58	3.10	68.92
Unidentified fish	0.05	0.05	2.62	0.52	2.86	71.78
Unidentified corophium	0.06	0.00	2.47	0.36	2.70	74.49
Apocorophium lacustre	0.08	0.00	2.42	0.32	2.64	77.13
Leptochelia rapax	0.06	0.01	2.39	0.24	2.61	79.74
Hourstonius laguna	0.07	0.01	2.27	0.42	2.48	82.22
Unidentified tegastidae	0.00	0.07	2.13	0.68	2.33	84.56
Unidentified harpacicoid	0.02	0.04	1.91	0.57	2.09	86.65
Balanus improvisus	0.00	0.05	1.80	0.23	1.97	88.62
Palaemontes pugio	0.00	0.06	1.72	0.24	1.88	90.50

SIMPER results based on arcsine square root transformed proportional diet volume Bray-Curtis similiarities of Skilletfish (*Gobiesox strumosus*) diet taxa. Diet taxa are compared for within group similarity for large size class fish (> 45 mm SL). Contributions of taxa are listed in descending order of percentage contribution to total within group similarity. Taxa above 90% cumulative contribution are not included. Group average similarity is 11.41.

Species	**Average Abundance**	**Average Similarity**	**Similarity/SD**	**Contribution %**	**Cum.%**
Unidentified bryozoa	0.19	4.07	0.46	35.65	35.65
Eurypanopeus depressus	0.16	2.17	0.23	18.99	54.64
Unidentified eggs	0.15	1.45	0.30	12.74	67.38
Unidentified xanthid	0.09	1.17	0.30	10.26	77.63
Balanomorpha	0.14	0.53	0.10	4.68	82.32
Unidentified fish	0.04	0.41	0.24	3.56	85.88
Polydora spp.	0.03	0.41	0.29	3.56	89.44
Hourstonius laguna	0.07	0.29	0.10	2.51	91.95

SIMPER results based on arcsine square root transformed proportional diet volume Bray-Curtis similiarities of Skilletfish (*Gobiesox strumosus*) diet taxa. Diet taxa are compared for within group similarity for small size class fish (< 30 mm SL). Contributions of taxa are listed in descending order of percentage contribution to total within group similarity. Taxa above 90% cumulative contribution are not included. Group average similarity is 13.10.

Species	**Average Abundance**	**Average Dissimilarity**	**Dissimilarity/SD**	**Contribution %**	**Cum.%**
Eurypanopeus depressus	0.22	2.50	0.25	19.11	19.11
Unidentified tegastidae	0.15	2.36	0.40	18.04	37.15
Neathes succincea	0.20	2.22	0.25	16.94	54.09
Unidentified xanthid	0.15	1.88	0.23	14.38	68.47
Unidentified megalopa	0.12	1.14	0.23	8.71	77.17
Unidentified harpcaticoid	0.06	0.74	0.27	5.67	82.85

(continued).

Species	**Average Abundance**	**Average Dissimilarity**	**Dissimilarity/SD**	**Contribution %**	**Cum.%**
Apocorophium louisianum	0.09	0.63	0.16	4.83	87.68
Unidentified ostracoda	0.04	0.36	0.20	2.76	90.45

SIMPER results based on arcsine square root transformed proportional diet volume Bray-Curtis similiarities of Skilletfish (*Gobiesox strumosus*) diet taxa. Diet taxa are compared for within group similarity for medium size class fish (30 - 45 mm SL). Contributions of taxa are listed in descending order of percentage contribution to total within group similarity. Taxa above 90% cumulative contribution are not included. Group average similarity is 12.62.

Species	**Average Abundance**	**Average Similarity**	**Similarity/SD**	**Contribution %**	**Cum.%**
Eurypanopeus depressus	0.21	2.51	0.33	19.87	19.87
Unidentified megalopa	0.14	1.74	0.32	13.77	33.63
Unidentified xanthid	0.17	1.65	0.31	13.06	46.69
Balanomorpha	0.17	1.42	0.25	11.27	57.96
Neathes succinea	0.17	1.41	0.20	11.19	69.15
Unidentified bryozoa	0.12	1.11	0.28	8.80	77.95
Unidentified eggs	0.09	0.85	0.23	6.73	84.68
Unidentified tegastidae	0.04	0.48	0.23	3.78	88.45
Unidentified ostracoda	0.07	0.38	0.19	2.98	91.44

SIMPER results based on arcsine square root transformed proportional diet volume Bray-Curtis similiarities of Skilletfish (*Gobiesox strumosus*) diet taxa. Diet taxa are compared by profile type for between group dissimilarity. Contributions of taxa are listed in descending order of percentage contribution to total within group similarity. Taxa above 90% cumulative contribution are not included. Average dissimilarity was 92.26.

Species	**Average Abundance Large**	**Average Abundance Small**	**Average Dissimilarity**	**Dissimilarity/SD**	**Contribution %**	**Cum.%**
Eurypanopeus depressus	0.16	0.22	10.85	0.74	11.76	11.76
Neanthes succinea	0.02	0.20	6.97	0.56	7.56	19.32
Unidentified xanthid	0.09	0.15	6.97	0.67	7.55	26.87
Unidentified bryozoa	0.19	0.03	6.62	0.84	7.17	34.04
Balanomorpha	0.14	0.06	6.09	0.44	6.60	40.64
Unidentified tegastidae	0.00	0.15	5.37	0.52	5.82	46.45
Unidentified eggs	0.15	0.01	5.15	0.46	5.58	52.04
Unidentified megalopa	0.02	0.12	4.30	0.52	4.66	56.70
Hourstonius laguna	0.07	0.06	4.12	0.46	4.47	61.17
Apocorophium louisianum	0.03	0.09	3.72	0.48	4.03	65.20
Unidentified arthropoda	0.05	0.04	2.66	0.33	2.88	68.08
Unidentified harpcaticoid	0.01	0.06	2.29	0.49	2.49	70.57
Palaemontes pugio	0.04	0.04	2.29	0.28	2.48	73.05
Unidentified fish	0.04	0.04	2.09	0.54	2.27	75.32
Penaeus setiferus	0.06	0.00	1.99	0.22	2.16	77.47
Unidentified ostracoda	0.02	0.04	1.85	0.59	2.00	79.47
Unidentified zoea	0.00	0.05	1.80	0.20	1.95	81.43
Gobiesox strumosus	0.05	0.00	1.63	0.22	1.77	83.20
Polydora spp.	0.03	0.01	1.57	0.49	1.70	84.90
Balanus improvisus	0.02	0.02	1.46	0.21	1.58	86.47
Leptochelia rapax	0.01	0.02	1.45	0.21	1.57	88.05

(continued).

Species	Average Abundance Large	Average Abundance Small	Average Dissimilarity	Dissimilarity/SD	Contribution %	Cum.%
Monocorophium acherusicum	0.03	0.01	1.35	0.34	1.46	89.51
Paracaprella tenuis	0.02	0.02	1.29	0.30	1.39	90.90

SIMPER results based on arcsine square root transformed proportional diet volume Bray-Curtis similiarities of Skilletfish (*Gobiesox strumosus*) diet taxa. Diet taxa are compared by profile type for between group dissimilarity. Contributions of taxa are listed in descending order of percentage contribution to total within group similarity. Taxa above 90% cumulative contribution are not included. Average dissimilarity was 88.52.

Species	Average Abundance Large	Average Abundance Medium	Average Dissimilarity	Dissimilarity/SD	Contribution %	Cum.%
Eurypanopeus depressus	0.16	0.22	10.85	0.74	11.76	11.76
Neanthes succinea	0.02	0.20	6.97	0.56	7.56	19.32
Unidentified xanthid	0.09	0.15	6.97	0.67	7.55	26.87
Unidentified bryozoa	0.19	0.03	6.62	0.84	7.17	34.04
Balanomorpha	0.14	0.06	6.02	0.44	6.60	40.64
Unidentified tegastidae	0.00	0.15	5.37	0.52	5.82	46.45
Unidentified eggs	0.15	0.01	5.15	0.46	5.58	52.04
Unidentified megalopa	0.02	0.12	4.30	0.52	4.66	56.70
Hourstonius laguna	0.07	0.06	4.12	0.46	4.47	61.17
Apocorophium louisianum	0.03	0.09	3.72	0.48	4.03	65.20
Unidentified arthropda	0.05	0.04	2.66	0.33	2.88	68.08
Unidentified harpcaticoid	0.01	0.06	2.29	0.49	2.49	70.57
Palaemontes pugio	0.04	0.04	2.29	0.28	2.48	73.05

(continued).

Species	**Average Abundance Large**	**Average Abundance Medium**	**Average Dissimilarity**	**Dissimilarity/SD**	**Contribution %**	**Cum.%**
Unidentified fish	0.04	0.04	2.09	0.54	2.27	75.32
Penaeus setiferus	0.06	0.00	1.99	0.22	2.16	77.47
Unidentified ostracoda	0.02	0.04	1.85	0.59	2.00	79.48
Unidentified zoea	0.00	0.05	1.80	0.20	1.95	81.43
Gobiesox strumosus	0.05	0.00	1.63	0.22	1.77	83.20
Polydora spp.	0.03	0.01	1.57	0.49	1.70	84.90
Balanus improvisus	0.02	0.02	1.46	0.21	1.58	86.47
Leptochelia rapax	0.01	0.02	0.15	0.21	1.57	88.05
Monocorophium acherusicum	0.03	0.01	1.35	0.34	1.46	89.51
Paracaprella tenuis	0.02	0.02	1.29	0.30	1.39	90.90

SIMPER results based on arcsine square root transformed proportional diet volume Bray-Curtis similiarities of Skilletfish (*Gobiesox strumosus*) diet taxa. Diet taxa are compared by profile type for between group dissimilarity. Contributions of taxa are listed in descending order of percentage contribution to total within group similarity. Taxa above 90% cumulative contribution are not included. Average dissimilarity was 88.10.

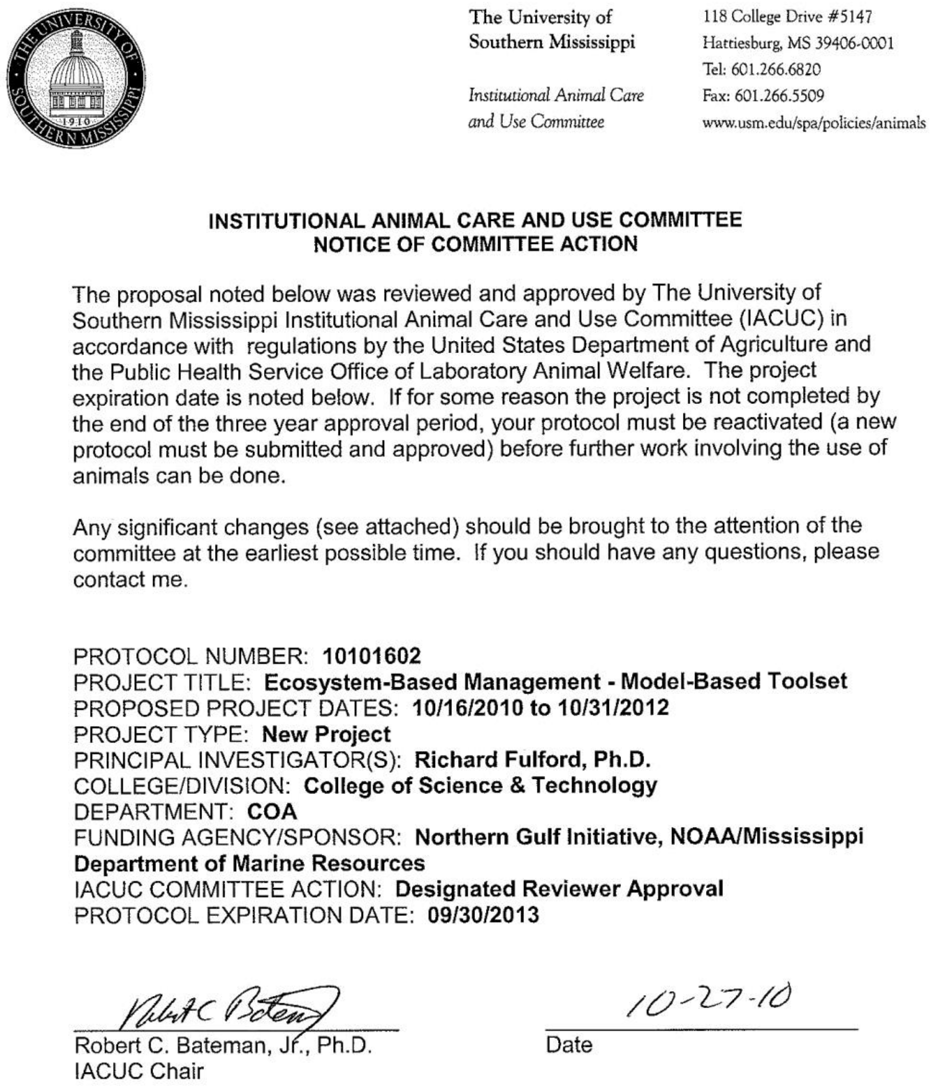
Species	**Average Abundance Small**	**Average Abundance Medium**	**Average Dissimilarity**	**Dissimilarity/SD**	**Contribution %**	**Cum.%**
Eurypanopeus depressus	0.22	0.21	10.27	0.77	11.66	11.66
Neathes succinea	0.20	0.17	9.56	0.66	10.85	22.51
Unidentified xanthid	0.15	0.17	8.16	0.68	9.27	31.78
Unidentified megalopa	0.12	0.14	6.58	0.62	7.47	39.25
Balanomorpha	0.06	0.17	5.78	0.58	6.56	45.81

(continued).

Species	**Average Abundance Small**	**Average Abundance Medium**	**Average Dissimilarity**	**Dissimilarity/SD**	**Contribution %**	**Cum.%**
Unidentified tegastidae	0.15	0.04	5.09	0.58	5.78	51.59
Unidentified bryozoa	0.03	0.12	3.85	0.60	4.37	55.96
Apocorophium louisianum	0.09	0.03	3.47	0.49	3.93	59.89
Hourstonius laguna	0.06	0.04	3.04	0.42	3.45	63.34
Unidentified eggs	0.01	0.09	3.01	0.54	3.42	66.76
Palaemontes pugio	0.04	0.06	2.91	0.31	3.30	70.06
Unidentified ostracoda	0.04	0.07	2.87	0.52	3.26	73.32
Unidentified harpcaticoid	0.06	0.03	2.52	0.57	2.86	76.19
Balanus improvisus	0.02	0.05	2.05	0.26	2.32	78.51
Apocorophium spp	0.01	0.05	1.77	0.20	2.00	80.51
Unidentified zoea	0.05	0.00	1.63	0.20	1.85	82.36
Unidentified fish	0.04	0.02	1.62	0.45	1.84	84.19
Unidentified arthropda	0.04	0.01	1.48	0.28	1.68	85.88
Polydora spp.	0.01	0.04	1.37	0.51	1.56	87.44
Unidentified decapoda	0.00	0.04	1.36	0.17	1.55	88.98
Apocorophium lacustre	0.01	0.03	1.25	0.20	1.42	90.40

APPENDIX B

INSTITUTIONAL ANIMAL CARE AND USE COMMITTEE APPROVAL FORM



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The University of
Southern Mississippi

*Institutional Animal Care
and Use Committee*

118 College Drive #5147
Hattiesburg, MS 39406-0001
Tel: 601.266.6820
Fax: 601.266.5509
www.usm.edu/spa/policies/animals

INSTITUTIONAL ANIMAL CARE AND USE COMMITTEE
NOTICE OF COMMITTEE ACTION

The proposal noted below was reviewed and approved by The University of Southern Mississippi Institutional Animal Care and Use Committee (IACUC) in accordance with regulations by the United States Department of Agriculture and the Public Health Service Office of Laboratory Animal Welfare. The project expiration date is noted below. If for some reason the project is not completed by the end of the three year approval period, your protocol must be reactivated (a new protocol must be submitted and approved) before further work involving the use of animals can be done.

Any significant changes (see attached) should be brought to the attention of the committee at the earliest possible time. If you should have any questions, please contact me.

PROTOCOL NUMBER: **10101602**
PROJECT TITLE: **Ecosystem-Based Management - Model-Based Toolset**
PROPOSED PROJECT DATES: **10/16/2010 to 10/31/2012**
PROJECT TYPE: **New Project**
PRINCIPAL INVESTIGATOR(S): **Richard Fulford, Ph.D.**
COLLEGE/DIVISION: **College of Science & Technology**
DEPARTMENT: **COA**
FUNDING AGENCY/SPONSOR: **Northern Gulf Initiative, NOAA/Mississippi Department of Marine Resources**
IACUC COMMITTEE ACTION: **Designated Reviewer Approval**
PROTOCOL EXPIRATION DATE: **09/30/2013**

Robert C. Bateman, Jr., Ph.D.
IACUC Chair

10-27-10
Date

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