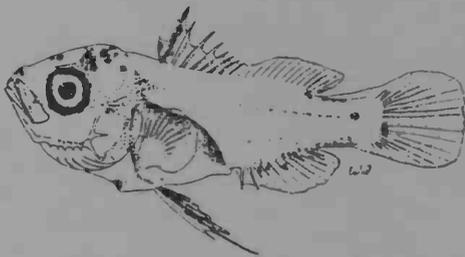


**A comparison of vertical distribution
patterns and sampling methods for
late stage reef fish larvae in the San
Blas Islands, Caribbean Panama.**



Thesis by Iris Hendriks
for the Department of Marine Biology,
Rijksuniversiteit Groningen

Supervisors:
Dr. M. Meekan, Australian Institute of Marine Science
Dr. W.W.C. Gieskes, Rijksuniversiteit Groningen

September 1997- March 1998

Abstract

This study compared three different methods to sample late-stage reef fish larvae around the field station of the Smithsonian Tropical Research Institute in the San Blas Islands, Caribbean Panama. Active sampling with a dip net around a kerosene and a fluorescent light was compared to sampling using an automated light trap. Catches among the three methods differed in taxonomic composition and timing. The families Gerriidae, Labrisomidae and Labridae dominated active netting. Gobiidae and Haemulidae dominated light trap catches. This suggests there is a difference in larval susceptibility to the different techniques, possibly behavioral. The varying timings of the catches for the different techniques support this theory. The vertical distribution of coral reef fish larvae was examined using light traps. This study showed there are clear patterns of vertical distribution in late stage reef fish larvae. Pomacentrids, Lutjanids and Gerrids dominated shallow traps while deep traps were dominated by catches of Apogonids, Gobiids and Acanthurids. These patterns are family dependent with only one or two species within a family demonstrating different behavior. These consistent patterns of vertical distribution dispel theories of larvae as passive particles in the water column. Specifically, this study implies that the late stage coral reef fish larvae are capable of directed swimming and actively maintain their position in the water column.

Table of contents

| | |
|--|----|
| Abstract | i |
| Table of contents | ii |
| Chapter 1 | |
| General introduction | 1 |
| Chapter 2 | |
| <i>A comparison of light trap and active netting around light sources as methods of sampling the late stag larvae of coral reef fishes</i> | |
| Introduction | 5 |
| Methods | 7 |
| Results | 11 |
| Discussion | 15 |
| Chapter 3 | |
| <i>Patterns in the vertical distribution of late stage fish larvae in the nearshore waters of coral reefs</i> | |
| Introduction | 17 |
| Methods | 19 |
| Results | 20 |
| Discussion | 28 |
| Chapter 4 | |
| General Discussion | 32 |
| Acknowledgments | |
| References | |
| Appendices | |

Chapter 1. General Introduction.

Most adult reef fishes occupy habitats that are patchy at a variety of spatial scales. Despite the barriers between patches, genetic isolation of sub-units of the population is unlikely, as virtually all reef fishes have a larval stage that resides in the plankton for weeks to months and is widely dispersed (Leis 1991). This larval phase links patches of habitat together creating networks or “meta-populations” (Roughgarden and Isawa 1986, Roughgarden *et al* 1987). Quantification and description of the links between sub-populations has become a major aim of research in coral reef environments (Sale 1991). This work seeks to identify habitat patches that act as reproductive sources and those that act as recruitment sinks and the mechanisms by which larval transport occurs (eg Roberts 1997). Such information is vital to the management of fish populations, as research during the last decade has demonstrated that the numbers of new individuals arriving from the plankton and recruiting into reef habitats is a major determinant of adult population size (Doherty and Fowler 1994).

In order to understand how assemblages of reef fishes are organised and linked together as meta-populations, we firstly require comprehensive descriptions of the distribution and behaviour of their larvae. Prior to the mid-1980's, such information was virtually non-existent in coral reef environments. A few studies had used towed nets to describe the distribution patterns of larvae close to and distant from reefs, although the difficulties of sampling pelagic environments using these conventional techniques limited the resolution of this work to very broad spatial scales (100's of km) (Leis and Miller 1976, Leis 1991). Problems included net avoidance by the more agile, older larval forms, small sample sizes and the inability to sample simultaneously at more than one spatial scale. The lack of older larvae in catches was a particularly critical point, since these forms are the survivors of the processes of mortality and dispersal in the plankton thus the most relevant to the formulation of hypotheses about connectivity among reef habitats. Problems were further compounded by the taxonomic difficulties in identifying the very young larvae in the diverse fauna of fish captured by nets (Leis and Rennis 1983). As a result, hypotheses about larval distributions were for the most part generated from a description of the patterns of newly settled individuals (Doherty and Williams 1988). However, use of

this retrospective method in turn created a new set of complications, as settlement patterns could be created by a variety of processes occurring both prior to and after pelagic life such as spawning and post-settlement mortality (Robertson et al. 1988, Jones 1991, Hixon 1991, Meekan et al. 1992).

These problems led to the development of new methods of sampling pelagic environments by researchers in the latter half of the 1980's and early 1990's. The first of these involved the use of plankton purse seine nets that were used to target the older larval stages of reef fishes associated with linear oceanographic features such as surface slicks and internal waves (Kingsford and Choat 1985, 1986) or aggregated around floating objects (Leis 1991). While this solved the problem of the capture of the older larval forms, the technique was ship-based and thus could not sample synoptically. A second method involved the use of stationary plankton nets that were placed in areas of high current flow such as reef crests or passes that were transited by larvae on their return from the plankton to adult habitats (Dufour 1991, Shenker et al. 1992, Thorrold et al. 1994 a, b). In common with the previous technique, this method effectively sampled the late larval stages of reef fishes. However, it requires suitable environments for deployment of the nets, restricting sampling to only a small subset of the locations inhabited by reef fishes. A third method developed to sample late stage larvae relies on the observation that the older larval stages of reef fish and many invertebrates are attracted to light (Verheijen 1958, Blaxter 1970). Doherty (1987) adapted this behaviour as a means of sampling larval fish and developed an automated light trap in the mid 1980's. Since this time, sampling using light traps has proven increasingly popular with researchers in coral reef environments. In contrast to the other methods outlined above, light traps can be deployed at a range of localities and distances from the reef and be set to sample automatically providing a truly synoptic picture of larval distribution and abundance.

The improved ability to target the older larval stages offered by these sampling methods has had implications for long-held views about the behaviour, distribution and dispersal of the larvae of coral reef fishes. Traditionally, larvae were thought to be passively dispersed within the plankton. Modelling of the transport of larvae assumed that they acted as passive scalars of water movement and as a consequence, could be

transported hundreds of kilometres in only a few weeks (Williams et al. 1984). This is a relevant time scale considering that the larval lives of most species are more than 3 weeks long (Brothers et al. 1983, Victor 1986). Consequently, it was argued that larval dispersal linked sub-populations of reef fishes at very large spatial scales (100's to 1000's of km) and that "stocks" of reef fishes (self-sustaining units of population, *sensu* Brooke 1981) could only exist at scales that encompassed very large portions of species distributions. Recent studies that have used light traps to collect late stage larvae have shown that this assumption of passive dispersal is likely to be incorrect. Wolanski et al. (1997) demonstrated that just prior to settlement, larvae were capable of detecting and swimming towards reefs. They suggested that this behaviour was likely to markedly reduce dispersal distances during planktonic life. Other evidence that larvae cannot be regarded as passively dispersed objects is provided by behavioural studies that have used late stage larval fish sampled by light traps. Experiments with these fish have shown that the late pelagic stages of many common families such as acanthurids, chaetodontids, lethrinids and lutjanids are very capable swimmers, with most able to cover distances from 10's to 100's of km during their larval lives (Stobutzki and Bellwood 1997). This swimming ability could have a major influence on dispersal ability and distance.

Despite the results of these and a variety of other studies that have used new sampling technologies to sample distributions of larval fish, the assumption that larvae are routinely dispersed by passive drift with currents over great distances during planktonic life still persists (eg. Roberts 1997). One of the possible reasons for this growing dichotomy of views is that much of the work involving the use of new methods of sampling larval fish (particularly light traps), has largely been confined to the western Pacific, notably the Great Barrier Reef (GBR). Many of these research programs now have a decade-long history of sampling. Researchers in the Caribbean region have been slower to adopt these technologies (but see Shenker et al. 1993, Thorrold *et al.* 1994a,b), thus may have been reluctant to alter traditional views on the ability of larvae to direct their movements and the role this may play in determining the spatial scales at which stocks of reef fish occur.

Here light traps were used to sample the distribution patterns of late stages of larval fish in the San Blas Islands, Caribbean Panama. This study addresses 2 issues. The first of these is relevant to the comparison of results of light trap studies among geographic localities such as the GBR and the Caribbean. The results of 2 methods of collecting larval fish using light aggregation devices (light traps and active netting around light sources) are compared. In a previous study in the San Blas Islands, Victor (1986) used active netting around a light source to capture larval fish. The composition of his catches differed markedly from those of light trap studies on the GBR (Victor 1986, unpubl data). Such contrasting catches may reflect real differences in the composition of larval fish communities and thus differences in their behaviour and dispersal abilities between localities. Alternatively, these results may simply be due to the differing sampling methods used in the Caribbean and on the GBR. These hypotheses are examined in Chapter 2. In Chapter 3, light traps were used to describe the vertical distribution of larvae in the waters close to reefs. This part of this thesis addresses the question: "Are there predictable patterns in the vertical distribution of larval fish prior to settlement?". Consistent patterns maintained over time would imply that late stage reef fish larvae are capable of directing their dispersal and maintaining their position in the water column in the San Blas Islands, suggesting that it is unlikely that they will be passively dispersed by water currents.

Chapter 2. A comparison of light traps and active netting around light sources as methods of sampling the late stage larvae of coral reef fishes.

Introduction.

Despite the growing importance of light traps as a sampling tool, relatively few studies have attempted to examine the biases inherent in this sampling method. Choat et al. (1993) concurrently sampled plankton purse seines, net tows and light traps in the waters around a single coral reef in order to compare the selectivity of the different techniques. Their study demonstrated that there was relatively little overlap in catches between methods and that each selectively targeted a particular portion of the ichthyoplankton fauna. Catches in towed nets and purse seines were found to be dominated by gobiids and apogonids, while light trap catches were dominated by different families of reef fishes, notably pomacentrids. This family contributed 93% of total catches by this method. Towed and pursed nets collected younger, smaller larvae, than light-traps.

Other studies have rigorously compared the performance of traps and nets (Gregory and Powles 1988), or evaluated the relative efficiency of different trap designs (Cope et al. 1996, Hernandez and Lindquist 1996), with data sets characterised by low and variable CPUE (Catch Per Unit Effort). In a different approach, Milicich (1993) determined the phototactic responses of one small reef fish and predicted positive orientation by individuals almost 100m away from a light source in relatively clear water. However, a recent study (Meekan et al. in press) used a simple mark-recapture experiment to show that light-traps have very low efficiency. They calculated that, at best, light traps sample only a small fraction (approximately 10%) of the larvae available for capture.

In the San Blas Islands, Caribbean Panama, Victor (1986) has previously used light to aggregate larval fish. They were captured using a small dip net that was swept through the area illuminated by a kerosene lamp. Captures using this technique were dominated by labrids (Victor 1986, unpubl data). In contrast, catches made by light traps on the Great Barrier Reef (GBR) are generally dominated by pomacentrids, gobies and apogonids, while labrids were only a very rare component of the total catch (Doherty 1987, Milicich 1988, Choat et al. 1993). This difference in catch composition may reflect a real difference in the

composition of larval fish communities between these sampling localities. Alternatively, it may be an artefact of the differing sampling methods used in the different localities. Here these hypotheses are examined by comparing catches of larval fish that were sampled concurrently in the same water mass using active netting around a light and light traps.

Methods.

Study Site.

The San Blas Islands form an archipelago, extending along the Caribbean coast of Panama in Central America. The sites sampled in this study were near to the island of Porvenir in the western part of the archipelago (9°34'N, 78°58'W). A map of the area is shown in Figure 2.1. Sampling was conducted during the dry season which is characterised by very low precipitation, increased turbulence, strong and continuous trade winds, and a consistent current from the north (Robertson 1992). The tidal range is 0.6 m. Surface water temperatures ranged from 27 °C to 29 °C during the period of the study.

Light trap design and operation.

A cross-section of the light trap design used in this study is shown in Figure 2.2. The light trap was of a design currently in use by the Australian Institute of Marine Science (AIMS) and James Cook University (JCU) Townsville, on the GBR and the North-West Shelf of Australia. The trap consists of a single chamber with a tube running through its centre. The chamber was open to the outside by four horizontal slits, through which photo positive organisms could approach the light and enter the trap. Entrance slits were on each side of the trap and were 1.5 cm high by 25 cm wide at the entrance. The slits were tapered to discourage fish escaping after entering the trap. The chamber was made of Perspex to allow the light to radiate from the central tube. The tube housed a single 8 Watt fluorescent light tube powered by batteries in the watertight housing above the tube. A removable collection box was attached by straps underneath the trap. The box had mesh sides (500 µM) that permitted substantial water movement to help maintain the fish in good condition. The Perspex chamber was protected by an aluminium frame, which was also used as an attachment point for a surface buoy.

Trap deployment and sampling design.

Active netting and light traps were compared for 19 days centred around the new moon in the first month of sampling. Previous work at the research station showed that this period of time

encompassed 95% of the recruitment in the majority of lunar cycles in the San Blas Islands (D. Wilson, unpubl data). In the following month sampling was reduced to 15 days centred around the new moon and then further reduced to 11 days in the 3rd month of sampling due to bad weather conditions (Table 2.1). On each night, sampling commenced after dusk once it had become fully dark between 7 and 8 pm.

Two types of lights, a kerosene lamp and a fluorescent light, were used for the sampling using active netting. These were hung over the water from the end of docks at the Smithsonian field station. Each type of light was separated from the other by about 100m. Below each light, an aquarium dip net (mouth dimensions approx. 12 x 8 cm. with 100 µm mesh) was swirled through surface waters in the light bloom then periodically raised and the contents emptied in a container. The water below the light was sampled for 15 minutes and afterwards the catch was preserved in alcohol. Two types of lights were sampled sequentially, resulting in a total of 30 minutes sampling for each per night.

A light trap was deployed on a mooring adjacent to the station by boat. The trap was left for one hour, after which time it was removed from the water and the catch preserved in alcohol. Opening slits were approx. 0.5 m. below surface and 1 m. above the bottom.

The morning after sampling catches were sorted and counted. Catches were identified with the help of adult meristics and several works on identification of Caribbean reef fish-larvae (see Appendix A). Most fishes could be identified to species level, sometimes by means of growing out very small, unpigmented larvae in an aquarium until they could be positively identified.

Table 2.1 Days sampled around new moon (X).

| Lunar days | Cycle 1 | Cycle 2 | Cycle 3 |
|-------------|---------|---------|---------|
| -9 | X | | |
| -8 | X | | |
| -7 | X | X | X |
| -6 | X | X | X |
| -5 | X | X | X |
| -4 | X | X | X |
| -3 | X | X | X |
| -2 | X | X | X |
| -1 | X | X | X |
| 0(new moon) | X | X | X |
| 1 | X | X | X |
| 2 | X | X | X |
| 3 | X | X | X |
| 4 | X | X | |
| 5 | X | X | |
| 6 | X | X | |
| 7 | X | X | |
| 8 | X | | |
| 9 | X | | |

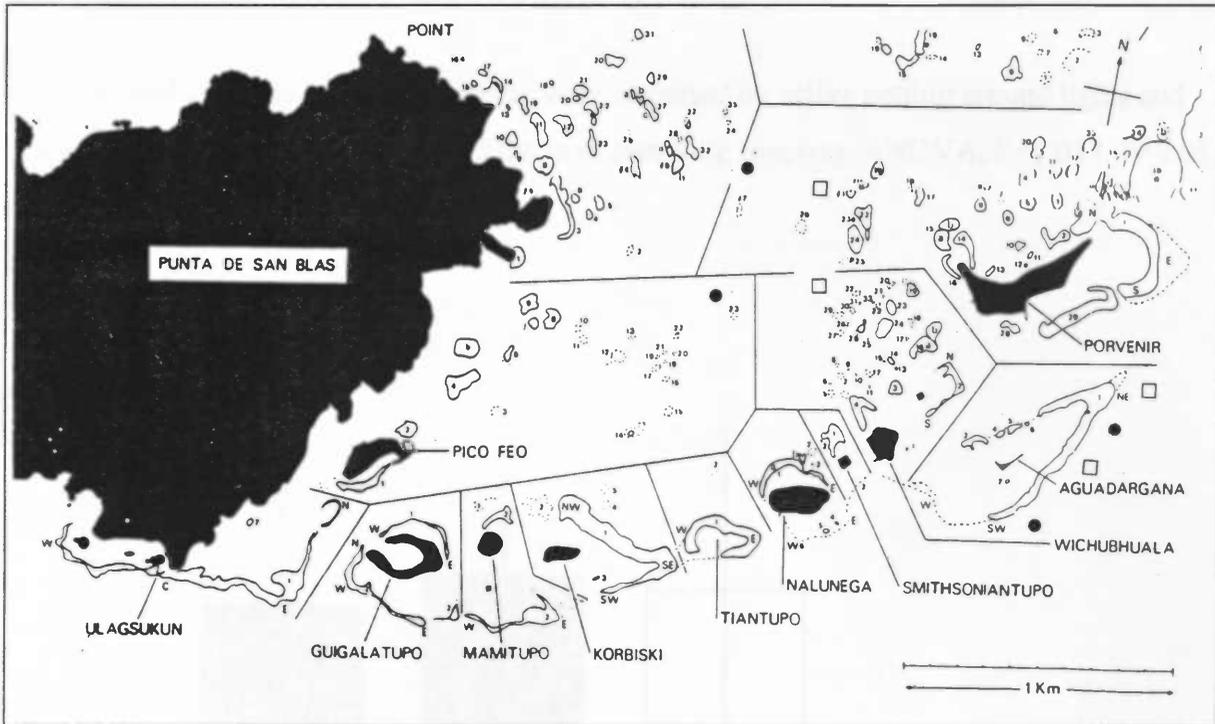


Fig.2.1 Map of the San Blas Islands, Caribbean Panama, showing the sampling sites. ■ is the Smithsonian Field station where the study was conducted. Sites used in the depth distribution experiment (Chapter 3) are also shown: ● are deep traps, □ are shallow traps. SR1, SR2 - Surface traps at Sail Rock. SRI, SRII - deep traps at 18 m. Sail Rock. L1, L2 - surface traps at the Lagoon. LI, LII - deep traps at 10 m. at the Lagoon.

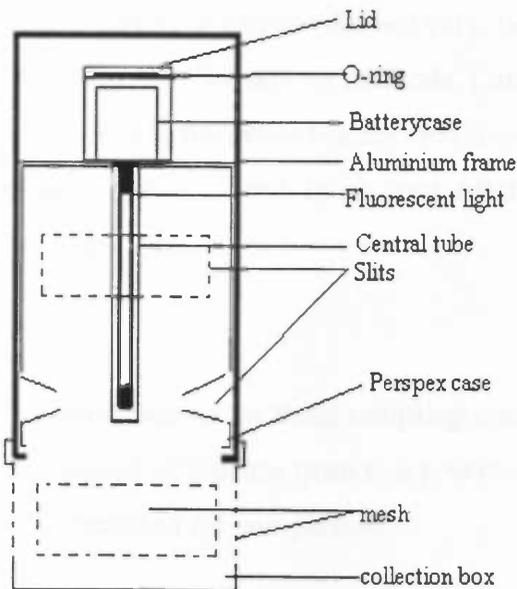


Fig 2.2. Cross-sectional diagram of light-trap design.

Results

Similar total numbers of reef fish larvae were collected by active netting around lights and light traps and averaged a total of 45 hours of sampling (oneway-ANOVA, $F=0.034$, $P=0.95$, Figure 2.3).

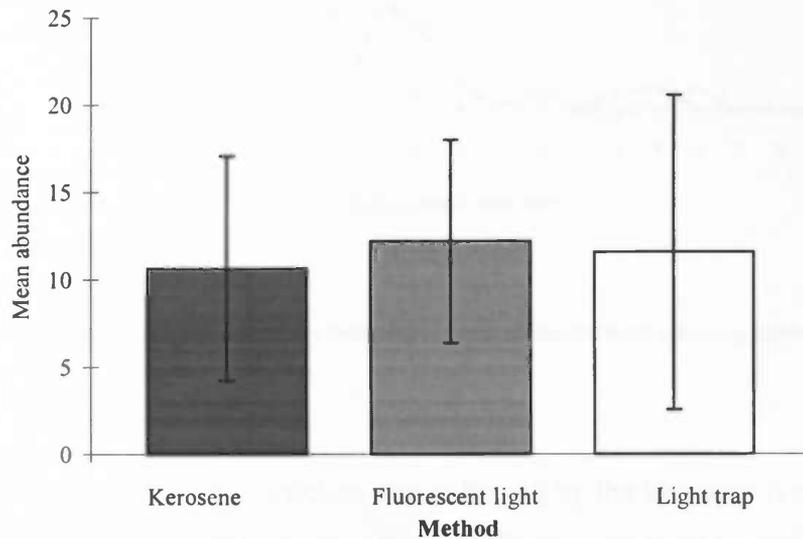


Fig. 2.3

Mean number of reef fish caught per hour sampling for three different methods. Error bars represent Standard Deviation.

While abundances of catches did not vary, there were clear differences both in the timing and composition of catches among methods. Catches using active netting around both kerosene and fluorescent lights peaked in the first few days of sampling and then declined through the rest of the sampling period. In contrast, catches using light traps peaked just before the new moon (Figure 2.4).

Catch composition of the three sampling methods is summarised in Table 2.2. In addition, the composition of catches from two previous studies that have used light traps to sample reef fishes are included for comparison.

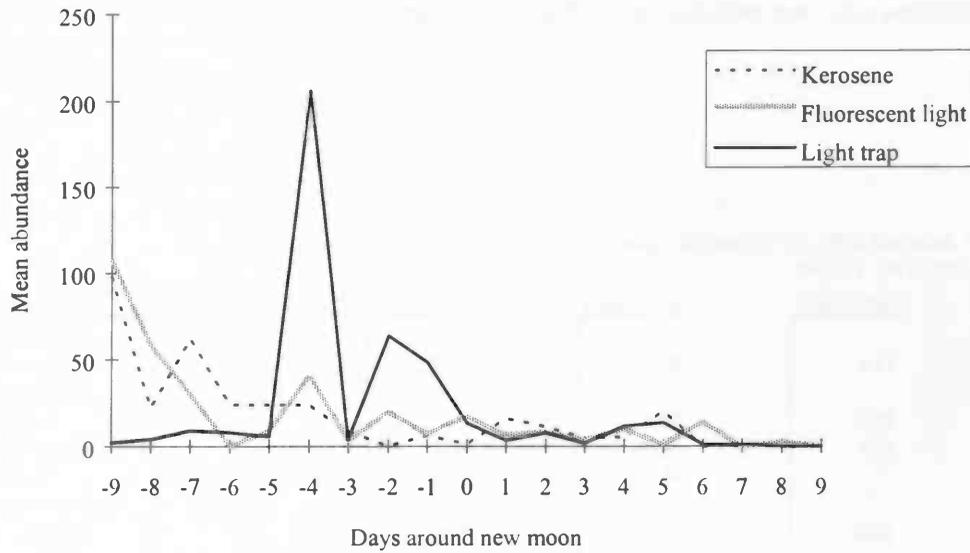


Figure 2.4

Mean numbers of fish collected each lunar day by each of the different sampling methods (per hour sampling).

The lowest diversity of catches was collected by the kerosene lamp, which caught 23 species from 15 families, while catches from the fluorescent light were composed of 39 species from 25 families and catches from the light trap, 42 species from 21 families.

Figure 2.5 shows the composition of the catches for each method for the eight most abundant families. Catches using the kerosene lamp and fluorescent light were both dominated by Gerreidae, Labrisomidae, Labridae and Monocanthidae, while catches using the light trap were dominated by the families Gobiidae, Haemulidae, Labridae and Labrisomidae.

Table 2.2

Composition of catches (in percentages of total catch) for different methods. Data from other authors is included for comparison.

| Family | | | | Milichich 1987-89, Lizard Island | | |
|-----------------|--------------|--------------|--------------|---|-------------------|-------------|
| | Kerosene | Fluo-light | Light trap | Sponaugle & Cowen 1991, 1992, Barbados, West Indies | Doherty 1987, GBR | Light trap |
| Acanthuridae | | | | 5.21 | | |
| Apogonidae | 1.85 | 1.02 | 0.71 | 0.55 | 1.11 | 5.50 |
| Aulostomidae | | | | 0.12 | | |
| Balistidae | | | | 0.06 | 0.14 | |
| Blenniidae | | 2.39 | 4.94 | 44.68 | 0.97 | 1.70 |
| Bothidae | 0.37 | | 0.71 | 0.34 | | |
| Bregmacerotidae | 0.37 | 0.34 | 0.18 | | | |
| Carangidae | | | 0.71 | 0.21 | 0.83 | 0.63 |
| Carapinae | | | | 0.67 | | |
| Chaenopsidae | | 0.34 | 0.18 | | | |
| Chaetodontidae | 0.37 | 0.34 | 0.18 | | 0.21 | |
| Dactylopteridae | | 0.34 | | | | |
| Diodontidae | 1.11 | | | | | |
| Eels | 1.48 | 0.34 | | | | |
| Elopidae | 3.33 | 2.39 | 0.35 | 0.64 | | |
| Engraulidae | | | | 0.49 | | |
| Fistularidae | | | | 0.03 | | |
| Gerreidae | 29.63 | 37.54 | 2.82 | 0.25 | | |
| Gobiesocidae | | 1.02 | 3.17 | 0.15 | | |
| Gobiidae | 5.19 | 3.75 | | 0.15 | 1.66 | 0.43 |
| Grammistidae | | | | 0.03 | | |
| Haemulidae | 4.07 | 3.07 | 48.50 | | | |
| Hemiramphidae | | 0.34 | 11.46 | | | |
| Holocentridae | | | | 0.8 | 0.76 | |
| Labridae | 10.00 | 11.95 | | 1.50 | | |
| Labrisomidae | 25.93 | 21.50 | 8.29 | | | |
| Lethrinidae | | | | | 1.24 | 14.8 |
| Lutjanidae | | | 6.70 | 1.01 | | |
| Microdesmidae | | | | 0.18 | | |
| Monacanthidae | 10.00 | 4.10 | | 5.84 | 0.83 | 0.13 |
| Mullidae | | | 4.76 | 0.06 | 0.21 | 0.80 |
| Muraenidae | | | | 0.06 | 0.07 | |
| Myctophidae | | | | 0.03 | | |
| Nemipteridae | | | | | 0.07 | |
| Ostraciidae | | | | 0.03 | | |
| Polynemidae | | | 0.18 | | | |
| Pomacentridae | 0.74 | 1.02 | | 19.58 | 88.04 | 54.6 |
| Priacanthidae | | | 0.18 | | | |
| Scaridae | | | | 13.64 | | |
| Scombridae | | 0.34 | | | 0.35 | 0.13 |
| Scorpaenidae | | 0.34 | 0.18 | 1.16 | 1.11 | |
| Serranidae | | 0.34 | 0.18 | 0.89 | | |
| Siganidae | | | | | | 0.13 |
| Soleidae | | 0.34 | 0.53 | | | |
| Sphyraenidae | | 0.34 | | | 0.21 | |
| Sygnathidae | | 4.10 | | 0.18 | 1.31 | 0.23 |
| Synodontidae | 5.56 | 2.05 | | 1.44 | | |
| Tetraodontidae | | 0.34 | 5.11 | 0.98 | | |

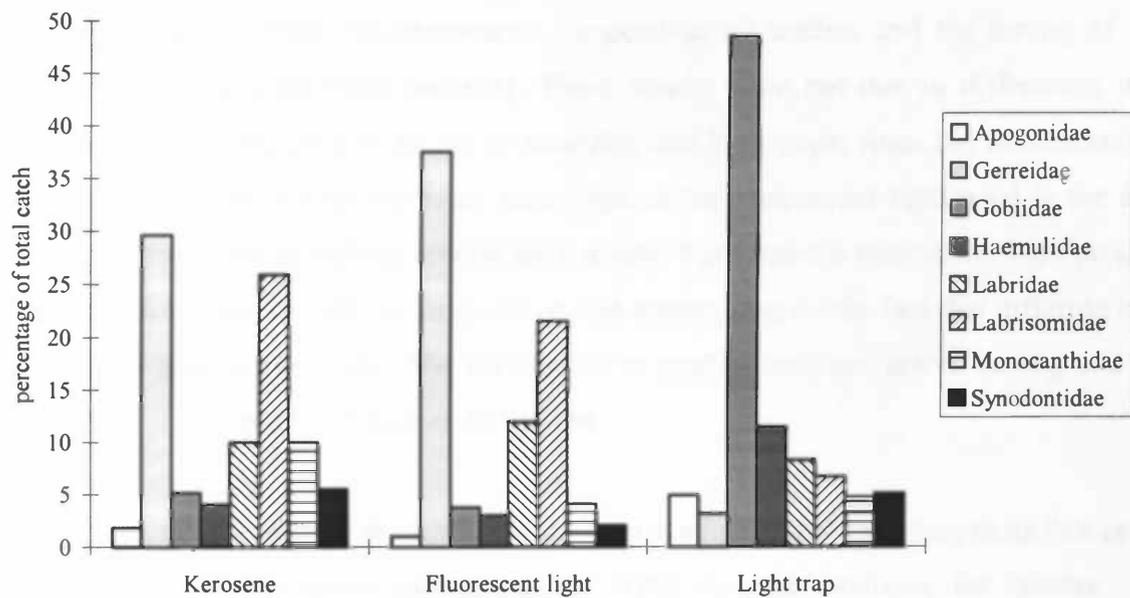


Figure 2.5.

Composition of catches compared for each method (in percentages of total catch) for the eight most abundant families.

Discussion.

While both active netting and light traps caught similar numbers of larval fish per hour sampling in the San Blas, the taxonomic composition of catches and the timing of those catches differed between these methods. These results were not due to differences in the quality or type of light used in the active sampling and light traps, since the fluorescent light used in the light trap was of the exact same type as the fluorescent light used in the active netting. Moreover, active netting around the kerosene light and the fluorescent light produced catches that were similar both in composition and timing, despite the fact that differing lamps were used to produce the light. The differences in catches between active netting and light traps may be best explained by larval behaviour.

Meekan et al. (in press) have shown that light traps are inefficient sampling tools that sample only a fraction of the larvae (approximately 10%) that are available for capture. They suggested that this may be due to behaviour of larvae, with many unable to locate tapered slits and enter the trap. If larvae lack the swimming ability to enter the trap in large numbers, it also seems likely that they will be unable to avoid capture in the process of active netting when the net is swept through the water. Examples of this type of larvae may include the families Gerreidae and Labrisomidae in this experiment. Catches of these families were abundant around the kerosene and fluorescent light, while very few were collected in the light trap. Conversely actively swimming larval fishes may be able to enter traps more easily, but also have enough swimming ability to avoid nets pulled through the water. Examples of larvae of this type may include the family Gobiidae and possibly the Haemulidae. Direct observations of larvae in the water around a light trap could provide correlative evidence to determine if larvae differ in their behaviour and ability to enter light traps.

This study suggests that the differences in taxonomic composition of catches recorded by previous studies that have used light to attract and capture larval fishes in the Caribbean (e.g. Victor 1986) and on the GBR (Doherty 1987, Milicich 1988) may be due to methodology, rather than a real difference in the composition of larval fish communities between localities. However the composition of light trap catches in this study is still very different than those of other studies that have used light traps to sample larval fish both in the Caribbean and on the GBR (Table 2.2, Doherty 1987, Sponaugle and Cowen 1991, 1992). Catches in these latter studies were dominated by pomacentrids and other families of reef fish, some of which were

not recorded by this study. In this case, these differences probably occur as a result of the timing of sampling in our study, rather than an effect of differing localities. Sponaugle and Cowen's (1991, 1992) data was collected over a two year period and included all the peak recruitment seasons of the various species. While Doherty (1987) sampled only a one month period, his sampling coincided with the period of peak recruitment of the families of reef fish such as pomacentrids that were most abundant in his samples. In contrast, sampling during this study was conducted during the dry season in the San Blas Islands, which does not coincide with the reproductive season of the families such as damselfishes in this region (Robertson et al. 1988). A longer term study that used light traps to sample larval fishes in the San Blas Islands over an 18 month period has confirmed that families such as pomacentrids dominate catches when sampling overlaps their reproductive seasons (D. Wilson, unpubl data).

If this hypothesis is correct and the difference as recorded in the composition of catches between active netting and light traps reflects the behaviour and swimming abilities of larval fish, then it might be expected that these families should also display differences in their feeding, distribution and dispersal in the plankton. In the next chapter one of these topics will be examined, the vertical distribution of larval fish in the nearshore waters around a coral reef.

Chapter 3. Patterns in the vertical distribution of late stage fish larvae in the nearshore waters of a coral reef.

Introduction.

Vertical distribution has a major influence on the patterns of movement of fish larvae in relation to currents and can strongly affect the coincidence of larvae and their prey (Leis 1991). Thus, descriptions of the vertical distributions are an essential prerequisite if the patterns of dispersal are to be understood. With one exception, previous studies of the vertical distribution of larval fish in the waters around coral reefs have used net tows to sample assemblages. Consequently, their results only describe the distribution patterns of very young larvae (see review by Leis 1991). In summary, these studies found that larval fish displayed taxon-specific patterns of vertical distribution. These patterns were most obvious during the day and tended to blur or breakdown during the night. Leis (1991) and Watson (1974) hypothesised that most larval fish had a taxon-specific preferred light level that determined daytime depth. At night, they suggested that larvae ceased feeding resulting in cessation of swimming and thus the spreading of vertical distribution patterns.

In contrast to previous studies that utilised net tows, Doherty and Carleton (1997) used light traps to describe vertical distribution patterns of older larval stages of reef fish at night in the waters around a coral reef on the GBR, Australia. The majority of these larvae were collected in traps that were deployed at the surface, although individuals of a few families, notably chaetodontids and holocentrids were only collected by traps deployed close to the bottom. While their study suggested that, similar to young larvae, older forms also display taxon-specific vertical distribution patterns, they sampled only a very narrow time window of a few days. This limited the variety of taxa collected by their sampling and resulted in relatively low catches, which may have limited the ability of statistical tests to discern spatial patterns.

At present it is unknown if the patterns described by Doherty and Carleton (1997) are representative of reef fishes in other localities, such as the Caribbean. In this chapter depth-related distribution patterns of the late-stage larvae of coral reef fish in the San

Blas Islands are described that were sampled using light traps during new moons for 3 consecutive months. This study addressed the question: do the late stage larvae of reef fishes at this Caribbean locality display taxon-specific depth distributions? These distribution patterns are then compared with those previously described for the young larval stages of reef fish collected by net tows and with older larval stages collected by light traps on the GBR.

Methods

I used light traps (Fig. 2.2) to sample larval fish during 3 consecutive lunar cycles in the San Blas Archipelago. The duration of each cycle was 19 days, centred around new moon. As noted in Chapter 2, previous studies at this locality have shown that approximately 95% of all photo positive reef fish larvae recruit within this 19 day period (D. Wilson, unpubl data). The sampling nights for each cycle were as follows: Cycle 1 - 21 October 1997 to 8 November 1997, Cycle 2 - 20 November 1997 to 8 December 1997, Cycle 3 - 20 December 1997 to 7 January 1998.

Light traps were deployed at two sites, the first within the lagoon and the other at Sail Rock (Fig. 2.1). The latter site was exposed the prevailing winds. Water depth at the lagoon site was 10m, while depth at the Sail Rock site was 18m. At each site, 4 traps were deployed on moorings, 2 approximately 1.5m below the surface and the remaining 2 approximately 2m above the bottom. Each trap was separated from its nearest neighbour by at least 100 m to eliminate interference on catches by the light fields of adjacent traps.

The light traps were deployed at dusk each night and retrieved the following day at dawn. After the traps were cleared, fishes were immediately sorted from the invertebrates and catches were preserved in 75% ethanol. In a few samples with very large numbers of invertebrates and fish, the catch was subsampled. Wherever possible, catches of fish larvae were identified to species (Appendix A).

An agglomerative, hierarchical clustering technique was used to discern associations among the samples. Dissimilarity was calculated with the Czekanowsky-Dice coefficient (or Sørensen coefficient). Species were assigned to groups using the Gaugh (1982), maximum χ^2 1 df statistic.

Results

The three sampling cycles caught a total of 48,743 fish from 35 families. The shallow traps caught 23,321 fishes, while 25,422 fishes were collected in the deep traps (Fig. 3.1A) There was no significant difference between the mean percentage of fish caught in the shallow versus deep traps over the three cycles (t-test, $t=0.37$, $P=0.75$). Clupeoid fishes dominated catches and composed 87% of all fish collected during the sampling program. A total 6,223 reef fish larvae were collected, which were equally distributed between deep and shallow traps (Fig. 3.1B) (t-test, $t=-0.61$, $P=0.60$).

Traps deployed in the lagoon collected a total of 424 reef fishes from 20 families in the first cycle, 340 reef fishes from 20 families in the second cycle and 1,166 fishes of 22 families in the third cycle. In comparison, traps deployed at Sail Rocks collected a total of 1,340 reef fishes in the first cycle from 21 families, 1,252 reef fishes from 18 families during the second cycle and 1,741 fishes from 21 families during the third cycle. The most abundant families in catches were the Apogonidae, Gerreidae, Gobiidae, Labridae, Lutjanidae, Pomacentridae and Synodontidae. These families composed 88% of all reef fishes collected by the traps. Catch composition is summarised in Table 3.1.

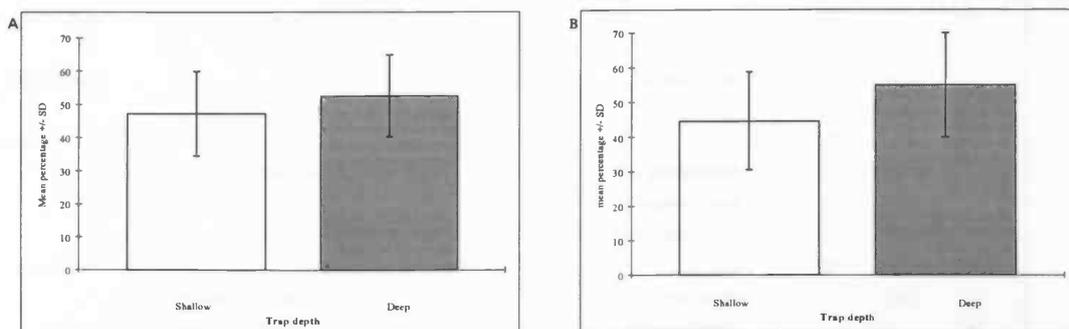


Figure 3.1

Mean percentage catch of fish in shallow and deep traps (pooled among months).

A: all fish. B: Reef Fish (excluding clupeoids). Error bars in all graphs represent Standard Deviation.

Table 3.1

Percentage composition of catches from shallow and deep traps pooled among months. Published data sets from other studies of depth distributions (Leis 1991, Doherty and Carleton 1997) of coral reef fishes are also included.

| Family | Taxa | Total | Shallow | Deep | Doherty and Carleton 1997 Catch composition (percent) of fishes from 46 shallow and 40 deep nocturnal trap sets. | | | Day |
|-------------------------|---------------------------------|-------|---------|-------|--|-------|-------|--|
| | | | | | Taxa | Total | Shall | |
| Acanthuridae | | 0.23 | | | | | | Deep |
| | <i>Acanthurus bahianus</i> | | | 0.01 | 0.02 | | | |
| | <i>Acanthurus chirurgus</i> | | | 0.06 | 0.13 | | | |
| | <i>Acanthurus coeruleus</i> | | | | 0.01 | | | |
| Apogonidae | | 2.13 | | | | 1.47 | | Upper-Middle (1) Avoid neuston (5) Increase with depth (9) |
| | <i>Apogon maculatus</i> | | | 0.03 | 0.06 | 0.02 | | |
| | <i>Apogon pluvifrons</i> | | | 0.03 | | 0.83 | 0.02 | |
| | <i>Apogonid sp.</i> | | | 0.01 | 0.11 | 0.24 | 0.05 | |
| | Apogonidae sp. 1 | | | | 0.18 | 0.07 | 0.02 | |
| | Apogonidae sp. 2 | | | 0.03 | 0.43 | 0.02 | | |
| | Apogonidae sp. 3 | | | | 0.02 | 0.02 | 0.15 | |
| | Apogonidae sp. 4 | | | | 0.01 | | | |
| | Apogonidae sp. 5 | | | | 0.05 | | | |
| | <i>Astrypogon punctulatus</i> | | | 0.01 | 0.01 | | | |
| | <i>Astrypogon stellatus</i> | | | 0.39 | 0.02 | | | |
| | <i>Phaeoptyx conklini</i> | | | 0.01 | 0.41 | | | |
| | <i>Phaeoptyx pigmentarius</i> | | | 0.04 | 0.29 | | | |
| Balistidae | | | | | | 0.02 | 0.02 | Avoid neuston |
| Blenniidae | | 0.11 | | | | 0.76 | | Avoid neuston |
| | Blenniidae sp. 2 | | | | | 0.56 | 0.02 | |
| | <i>Ophioblennius atlanticus</i> | | | 0.06 | | 0.03 | 0.05 | |
| | <i>Parablennius marmoratus</i> | | | 0.01 | 0.03 | 0.03 | 0.05 | |
| | | | | | | 0.03 | 0.02 | |
| | | | | | | | | Increase with depth |
| Bothidae | | 0.01 | | | | | | |
| | <i>Bothus lunatus</i> | | | 0.01 | | | | |
| | <i>Bothus ocellatus</i> | | | | | | | |
| Bregmacerotidae | <i>Bregmaceros atlanticus</i> | 0.18 | 0.04 | 0.14 | | 0.02 | 0.02 | |
| Canthigasterinae | | | | | | 0.03 | 0.03 | |
| | | | | | | | | |
| Carangidae | | 0.07 | | | | 0.15 | | |
| | <i>Chloroscombrus chrysurus</i> | | | 0.05 | 0.01 | 0.08 | | |
| | <i>Decapterus sp.</i> | | | 0.004 | | 0.05 | | |
| | <i>Selene vomer</i> | | | | 0.004 | 0.02 | | |
| Chaetodontidae | | 0.03 | | | | 0.08 | | |
| | <i>Chaetodon capistratus</i> | | | | 0.02 | 0.02 | | |
| | <i>Chaetodon ocellatus</i> | | | | | | 0.05 | |
| | | | | | | | 0.02 | |
| Chaenopsidae | <i>Hemionblemaria simulus</i> | 0.03 | | 0.03 | | | | |

| Doherty and Carlton 1997 | | | | | Leis 1991 | | | | |
|--------------------------|---|-------|---------|------|-----------|-------|---------|------|-------------------------|
| Family | Taxa | Total | Shallow | Deep | Taxa | Total | Shallow | Deep | Pattern (Days) |
| Congridae | <i>Heteroconger halis</i> | 0.01 | | 0.01 | | | | | |
| Gerreidae | <i>Eucinostomus melanopterus</i> | 2.10 | 2.08 | 0.01 | | | | | |
| Gobiidae | | 1.77 | | | | | | | Increase with depth |
| | <i>Coryphopterus diurus</i> | | | 0.09 | | | | | |
| | <i>Coryphopterus glaucofraenum</i> | | | | | | | | |
| | <i>Coryphopterus personatus</i> | | | | | | | | |
| | <i>Gnatholepis thompsoni</i> | | 0.01 | 0.09 | | | | | |
| | <i>Gobiosoma saucrum</i> | | | 0.02 | | | | | |
| | Gobiidae sp. 1 | | | 0.17 | | | | | |
| | Gobiidae sp. 2 | | | 1.02 | | | | | |
| | Gobiidae sp. 3 | | | 0.11 | | | | | |
| | Gobiidae sp. 4 | | | 0.18 | | | | | |
| | Gobiidae sp. 5 | | | 0.02 | | | | | |
| | Gobiidae sp. 6 | | | 0.01 | | | | | |
| | Gobiidae sp. 7 (poss. <i>Nes longus</i>) | | | 0.04 | | | | | |
| Haemulidae | <i>Haemulon aurolineatum</i> | 0.09 | 0.09 | | | | | | |
| Holocentridae | <i>Holocentrus veillanus</i> | 0.01 | | 0.01 | | 0.51 | 0.34 | 0.17 | Upper-Middle (1) |
| Labridae | | 1.38 | 0.02 | 0.01 | | | | | Increase with depth (3) |
| | <i>Hulichoeres bivittatus</i> | | | 0.01 | | | | | Deep (2) |
| | <i>Hulichoeres gamoti</i> | | | | | | | | No pattern (1) |
| | <i>Hulichoeres maculipinna</i> | | | | | | | | |
| | <i>Hulichoeres poeyi</i> | | | | | | | | |
| | Labridae sp. 2 | | 0.03 | 0.67 | | | | | |
| | Labridae sp. 3 (poss. <i>H. picus</i>) | | | 0.17 | | | | | |
| | Labridae sp. 4 | | | 0.01 | | | | | |
| | Labridae sp. 5 | | | 0.01 | | | | | |
| | <i>Thalassoma bifasciatum</i> | | 0.39 | 0.04 | | | | | |
| Labrisomidae | | 0.02 | | | | | | | |
| | <i>Labrisomus nichipinnis</i> | | | 0.01 | | | | | |
| | <i>Milacocentrus macrops</i> | | | | | | | | |
| | <i>Milacocentrus triangulatus</i> | | 0.01 | | | | | | |
| Lutjanidae | | 0.46 | | | | | | | Increase with depth (1) |
| | <i>Lutjanus apodus</i> | | | 0.07 | | | | | |
| | <i>Lutjanus buccanella</i> | | | 0.02 | | | | | |
| | <i>Lutjanus chrysurus</i> | | | 0.03 | | | | | |
| | <i>Lutjanus mahogani</i> | | | 0.30 | 0.03 | | | | |
| Monacanthidae | <i>Monacanthus toffis</i> | 0.03 | 0.03 | | | 2.04 | 1.64 | 0.30 | |
| Mullidae | <i>Pseudupeneus maculatus</i> | 0.01 | 0.01 | | | 1.20 | 1.20 | | Upper (3) |

| Family | Taxa | Total | Shallow | Deep | Taxa | Total | Shallow | Deep | Pattern (D) |
|----------------------|---------------------------------|--------|---------|-------|--------------------------------|-------|---------|------|-------------|
| Pomacentridae | | 1.56 | | | | 3.96 | | | Upper |
| | <i>Abudefduf saxatilis</i> | | | | Pomacentrinae | 2.94 | | | |
| | <i>Segastes dorsopanicans</i> | | 0.54 | 0.03 | <i>Discyllus arams</i> | | 0.96 | 0.02 | |
| | <i>Segastes leucostictus</i> | | 0.03 | | <i>Pomacentrus coelestis</i> | | 0.69 | 0.05 | |
| | <i>Segastes planifrons</i> | | 0.52 | 0.04 | <i>Pomacentrus (ocellated)</i> | | 0.68 | 0.03 | |
| | <i>Segastes portius</i> | | 0.34 | 0.01 | <i>Dischistodus spp.</i> | | 0.20 | | |
| | <i>Segastes variabilis</i> | | 0.01 | 0.01 | <i>Abudefduf vagiensis</i> | | 0.14 | | |
| | <i>Microspathodon chrysurus</i> | | 0.01 | 0.00 | <i>Pomacentrus</i> | | 0.12 | 0.02 | |
| | | | | | Lepidogobys | | | | |
| | | | | | <i>Pomacentrus (unmetam)</i> | | 0.05 | | |
| | | | | | <i>Chrysiptera leucopoma</i> | | 0.02 | | |
| | | | | | <i>Discyllus trimaculatus</i> | | 0.02 | | |
| | | | | | <i>Neoglyphidodon nelsoni</i> | | | 0.05 | |
| | | | | | Chrominae | 1.02 | | | |
| | | | | | <i>Chronis atripetionis</i> | | 0.98 | 0.02 | |
| | | | | | <i>Chronis weberi</i> | | 0.02 | | |
| Priacanthidae | <i>Priacanthus orientalis</i> | 0.01 | | | | | | | |
| Scorpaenidae | <i>Scorpaenopsis regalis</i> | 0.03 | 0.02 | 0.01 | | 0.22 | 0.15 | 0.07 | |
| Scorpaenidae | | | | | | 0.03 | 0.03 | | |
| Serranidae | | 0.01 | | | | 0.03 | 0.03 | | Deep |
| Syngnathidae | | | | | | 0.06 | 0.05 | 0.03 | Deep |
| Synodontidae | <i>Synodus intermedius</i> | 1.43 | 0.52 | 0.91 | | 0.02 | | 0.02 | Deep |
| Teraponidae | | | | | | 0.02 | 0.02 | | |
| Trichuridae | <i>Trichurus lepturus</i> | 0.02 | | 0.02 | | | | | |
| Clupeoids | | 87.35 | 40.71 | 46.64 | | 88.5 | 66.7 | 22.8 | |
| Unidentified | | 0.79 | 0.15 | 0.64 | | | | | |
| Total catch | | 100.00 | 46.88 | 53.11 | | | | | |

Classification analysis based on all taxa split the samples into four clusters (Fig. 3.2) Both site and depth effects were evident in the data sets. The first split of the dendrogram separated catches made by deep traps at Sail Rock from all other catches. These catches were distinguished on the basis of the abundances of four taxa, Gobiidae sp. 2, *Phaeoptyx conklini*, Labridae sp. 2 and Apogonidae sp. 2. The next split separated catches made by deep traps in the lagoon from those of shallow traps at both sites. These shallow catches were distinguished on the basis of the abundance of *Eucinostomus melanopterus* and a pomacentrid, *Stegastes dorsopunicans*. Catches in shallow traps in the lagoon were split from those of shallow traps at Sail Rock by the abundance of an apogonid, *Astrapogon stellatus* and a labrid, *Thalassoma bifasciatum*. These site and depth effects in composition of catches are also summarised in Figure 3.3 where the species composition of each of the groups identified by the dendrogram is shown.

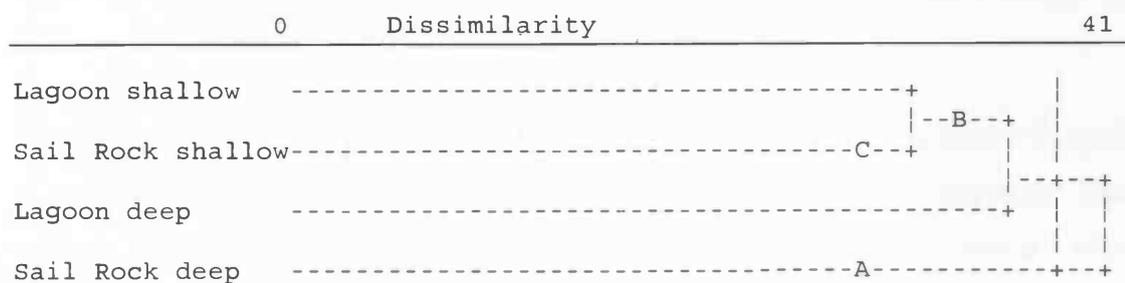


Figure 3.2

Dendrogram showing affinities among groups.

A: includes taxa: Gobiidae sp2, *Phaeoptyx conklini*, Labridae sp2, Apogonidae sp 2.

B: *Eucinostomus melanopterus*, *Stegastes dorsopunicans*.

C: *Astrapogon stellatus*, *Thalassoma bifasciatum*.

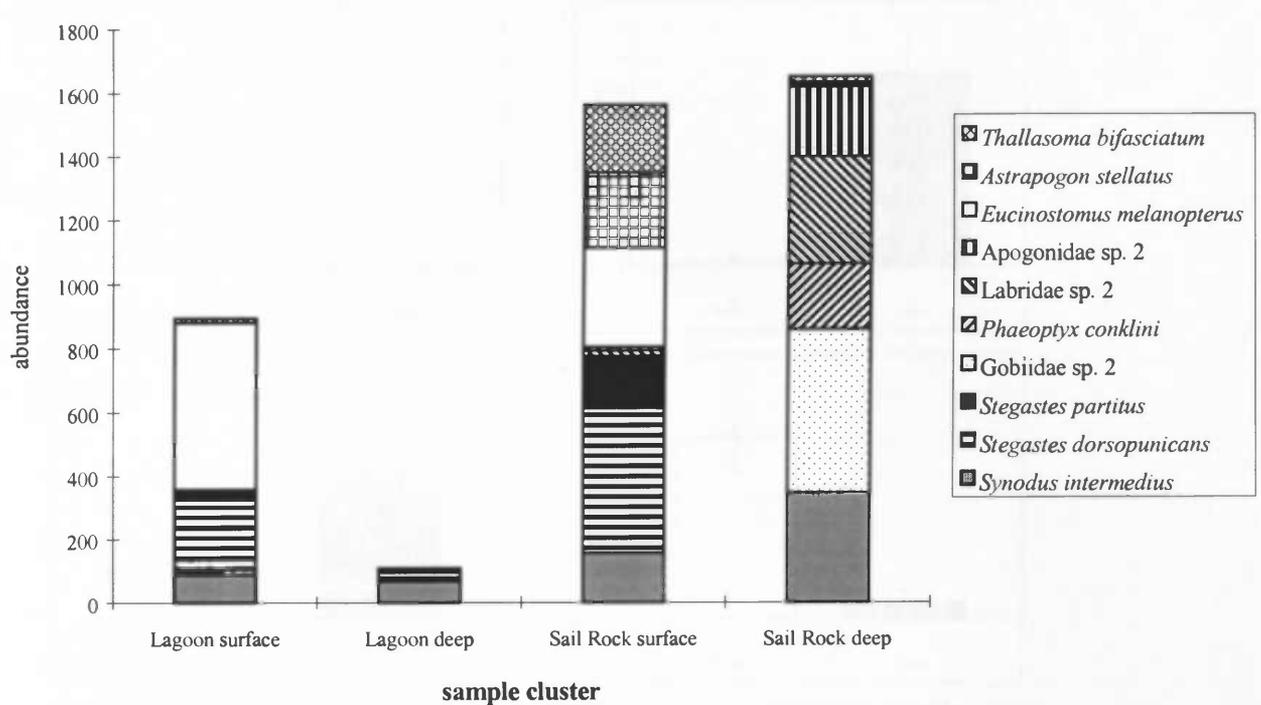


Figure 3.3 Composition of groups identified by the dendrogram. Species with total numbers of less than 150 individuals in catches and clupeids were excluded from these data sets .

The vertical distribution patterns of late stage larvae of the 8 most abundant families of reef fishes are summarised in Figure 3.4. All of these families displayed clear patterns of depth distribution. Both acanthurid and apogonid larvae were predominantly captured in deep traps, as were the larvae of gobies, labrids and synodontids. In contrast, the larvae of pomacentrids, lutjanids and gerrids were predominantly captured in shallow traps.

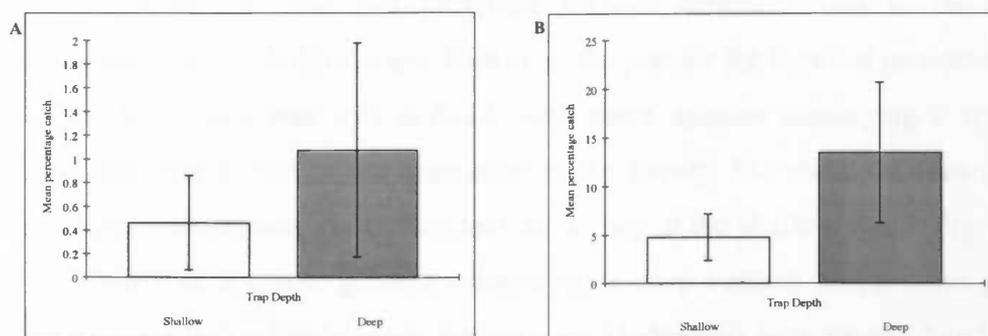


Figure 3.4 A,B Mean percentage catches of late stage larvae of A)Acanthuridae and B)Apogonidae in shallow and deep light traps (samples pooled among sites).

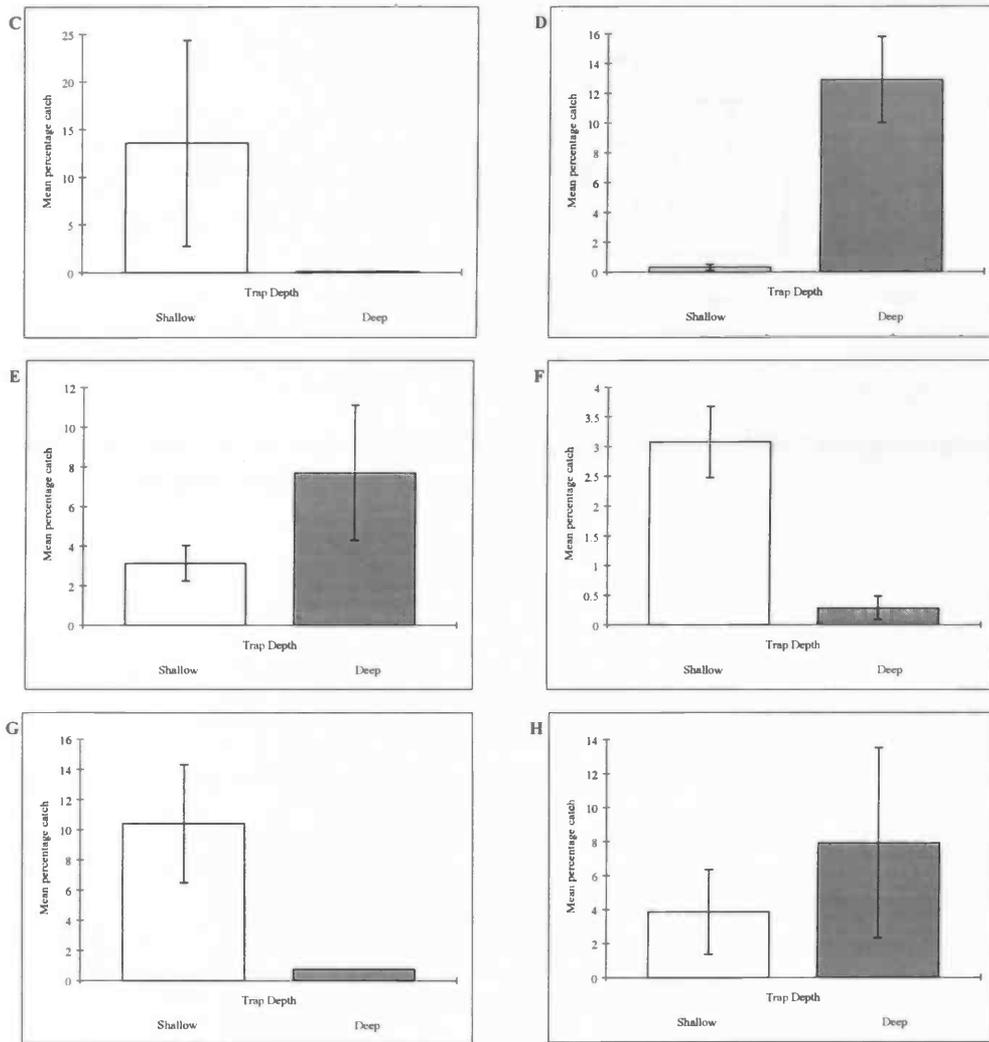


Figure 3.4 C, D, E, F, G, H

Mean percentage catches of late stage larvae of C)Gerreidae, D)Gobiidae, E)Labridae, F)Lutjanidae, G)Pomacentridae and H)Synodontidae in shallow and deep light traps (catches pooled among sites).

Those families of reef fish that preferred shallow depths tended to be almost exclusively captured in shallow traps. However, the pattern for families predominately captured in deep traps was less defined, with some species displaying a trend in abundance opposite to that of the remainder of the family. For example, *Astrapogon stellatus* (Apogonidae) was more abundant in catches in the shallow traps (Fig. 3.5A) while the family as a whole generally displayed a deep vertical distribution pattern (Fig. 3.4B). Similarly, *Thalassoma bifasciatum* (Labridae) was more abundant in catches in shallow traps (Fig. 3.5A), while most other members of this family were more abundant in catches in deep traps (Figure 3.4E).

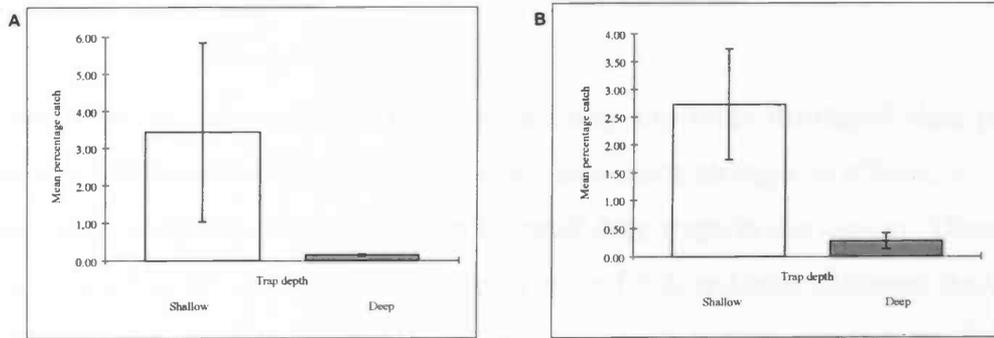


Figure 3.5

Mean percentage catches of late stage larvae of A) *Astrapogon stellatus* and B) *Thalassoma bifasciatum* in shallow and deep light traps (catches pooled among sites).

Discussion

The late stage larvae of coral reef fish collected by my study displayed clear patterns of vertical distribution. There were, however, also some strong site effects, as catches in deep traps at Sail Rock differed from those of deep traps in the lagoon. These latter catches were less diverse in terms of species of reef fish and also collected fewer total numbers of fish. This result may have been due to 2 factors: firstly, the shallower depth range in the lagoon (10m) resulting in the overlap of the volume of water illuminated by shallow and deep traps, and secondly, larvae encountering suitable settlement sites prior to their arrival in the lagoon, thus reducing both the range and abundance of species available for capture (Doherty et al. 1996)

While there were some similarities between the patterns of depth distribution recorded by my study and those described by Doherty and Carleton (1997) on the GBR, there were also some notable differences. In both the San Blas Islands and on the GBR, catches were dominated by clupeoids (87 and 88% of catches in these localities, respectively). On the GBR, 66% of these fish were captured in shallow traps while in the San Blas Islands, catches of clupeids were equally divided between shallow and deep traps. In the San Blas Islands, catches of reef fish were dominated by apogonids, which mostly occurred in deep traps. This family was also an important component of catches on the GBR, however these fishes were largely collected by traps deployed at the surface. In both localities, the majority of pomacentrids were collected by shallow traps. On the GBR, gobies and labrids were not collected by Doherty and Carleton's (1997) study, whereas in the San Blas Islands these families were important parts of the catch of reef fishes and were typically in traps deployed near the bottom. Some of these differences in catch composition between my study and that of Doherty and Carleton (1997) are almost certainly due to the timing of sampling. For example, the low numbers of pomacentrids collected by my study probably reflects the fact that my sampling did not occur during the reproductive season of this family. A similar problem may account for the absence of gobies and labrids in samples collected by Doherty and Carleton's (1997) study. Irrespective of these differences, both my study and that of Doherty and Carleton (1997) unequivocally demonstrate that late stage

larval fish from a great variety of families are controlling their vertical distribution in the water column in the days prior to their arrival on reefs.

The patterns of vertical distribution described by my study are consistent with those recorded for very young larvae captured by net tows on the GBR. Leis (1991) identified taxon-specific patterns of vertical distribution for early stage larval fish during the daytime in the GBR lagoon. With the exception of only 1 family (lutjanids), the patterns he recorded were consistent with those found at night in the San Blas Islands. At night, Leis (1991) found that patterns of vertical distribution tended to disperse and he suggested that that light was the cue utilized by larval fish to maintain their position in the water column (see also Watson 1974). As I found that larval fish maintained their positions during night, even during new moons when ambient light levels were at a minimum, it seems unlikely that light is a cue determining vertical distribution for late larval stages. Other possible cues for orientation at night may include sound (Sweatman 1988, Leis et al. 1996) or pressure.

The depth distributions displayed by larval fish in my study presumably confer some survival advantage. Larval fish occupying shallow depths are likely to be more subject to wind-driven surface currents. In the San Blas Islands winds blow towards or along the shore during winter months (R. Robertson unpubl. data). Thus, fish occupying very shallow depths would be more likely to be transported back to, or retained near adult reef habitats (Leis et al 1987, Leis and Reader 1991). However, residence in shallow water may increase mortality, as the predators of larval fish are thought to be more abundant in shallow water than in deep water (Bailey and Houde 1988). Furthermore, Victor (1991) has suggested that light at night in surface waters may enable predators to more easily locate prey species in shallow water. Thus, taxa that remain close to the bottom may do so in order to minimise predation. If this is the case, then it implies that there are differences in the swimming and/or orientation abilities of fish that are found in shallow depths compared to those that reside in deeper waters. These latter species should have greater swimming ability than those restricted to shallow waters, since they may not be retained near adult habitats by wind-driven current flows and thus may have to actively locate and swim to reefs.

Three lines of evidence support this hypothesis. Firstly, previous studies have shown clear ontogenetic changes in the depth distribution of some species. For example, Doherty and Carleton (1991) found that very young larval holocentrids were almost exclusively collected in shallow depths. However, as the larvae grew they became more widely dispersed in the water column, so that late stage larvae were most abundant near the bottom. Such changes in vertical distribution will be accompanied by changes in the mobility and sensory systems, so that the larvae resident in deeper water are also more agile than those at the surface.

A second line of evidence comes from the results of the comparison of sampling using active netting and light traps that I reported in the previous chapter. I hypothesised that the differences I saw between catches made by active netting and those collected by light traps reflected larval behaviour, so that the larval forms that were poor swimmers were more abundant in catches made by active netting. If this is the case then catches made by active netting should be dominated by species that occur in shallow waters, while catches made by light traps should be composed of a greater percentage of families that have deeper distributions. This prediction is generally supported by my results. For example, virtually all gerrids were collected in the surface traps and these were the most abundant component of the active netting catch. Similarly, the great majority of gobies were collected in deep traps and these taxa were far more abundant in light traps than in active netting samples. However, there were some families that displayed opposite trends. Labrids were most abundant in samples collected by active netting, yet this family was most abundant in catches made in light traps deployed near the bottom. This apparently contradictory result may be explained by the distribution of a single species, *Thalassoma bifasciatum*. In contrast to the remainder of the species within this family, which were most abundant in deep traps, *T. bifasciatum* was abundant at the surface and catches made by active netting were dominated by this species. This implies that *T. bifasciatum*, unlike the rest of the members of this family, may be a relatively poor swimmer.

A third line of evidence that supports the contention that “shallow” and “deep” taxa differ in swimming abilities is provided by the work of Stobutzki and Bellwood (1994). These workers captured late stage larval fishes using light traps and compared

the durations of sustained swimming that they were able to maintain in laboratory raceways. They found that the representatives of families such as chaetodontids and acanthurids, which are typically collected in relatively deep water on the GBR (Doherty and Carleton 1997), displayed far greater sustained swimming ability than representatives of families such as pomacentrids. These latter species are the dominant component of captures made in light traps deployed at the surface (Doherty and Carleton 1997).

These results imply that the depth distributions of these reef fishes may indeed represent a relative index of swimming ability. The approach of Stobutzki and Bellwood (1996) and Stobutzki (1997) is a means by which this hypothesis could be experimentally tested for Caribbean reef fishes. However, my hypothesis assumes that the patterns in vertical distribution seen at night are the same as those that occur in late stage larvae during the day. The evidence from daytime plankton net samples of young fish (Leis 1991) made suggests this may be the case, however this prediction will be difficult to test as few methods exist to capture late stage larvae during daylight hours. An alternative means of examining this hypothesis may be to directly observe the vertical distribution of late stage larval fish. This technique has been used on the GBR by Leis et al. (1996), who captured fish using light traps, released them during the day into the water column a kilometer or more distant from the nearest reef and then tracked the fish using SCUBA divers. These workers found that most species selected non-random positions in the water column, with many displaying a distinct depth preference.

In summary, my study adds to the growing body of evidence that the late stage larvae of reef fishes cannot be regarded as passively dispersed, but are active and agile members of the plankton. The implications of my results for prevailing models of connectivity of populations of reef fishes among reefs in the Caribbean is discussed in the following chapter.

Chapter 4. General Discussion.

Almost all coral reef fish possess a pelagic larval stage that is potentially capable of dispersal over large distances within the plankton (Leis 1991). Understanding the mechanisms that influence and control dispersal of this phase among sub-units of the metapopulation is a central goal of fisheries research. The older larval stages of reef fishes are the survivors of the processes of planktonic mortality, thus they offer an insight into the survival and dispersal of pelagic larvae. For this reason, light traps, a method that preferentially targets these older larvae, have rapidly become an important sampling technique.

Studies in the Caribbean and on the GBR that have used light to aggregate and collect larval fishes have collected faunas that had very different species compositions. Such differences may be the product of varying geographic areas, sampling techniques or behaviour by larval fish (Victor 1991). In Chapter 2 these possibilities were examined by simultaneously using 2 differing methods (active netting around a light source and light traps) to collect larval fish in the San Blas Islands. These methods caught similar numbers of larvae, however, the catches were composed of very different species. I suggested that the differences found between the techniques reflected larval behaviour, specifically swimming ability. The active netting technique preferentially selected species that were poor swimmers and could not avoid a net pulled through the water around a light source. In contrast, light trap catches were dominated by species with relatively good swimming ability that were able to locate and pass through entrance slits into the light trap. These same species were capable of avoiding the net used in the active netting sampling. Catches made by light traps in the San Blas were dominated by a fauna of reef fishes that was similar to that recorded by light trap sampling on the GBR. My results imply that differences in catches previously recorded by studies in the GBR and at the San Blas Islands were due to differences in sampling technique, rather than difference between geographic areas or larval behaviour.

In summary, my comparison of sampling techniques reinforces the point made by other studies (eg. Choat et al. 1993) that all methods currently in use for collecting

fish larvae are selective. Such differences in larval behaviour and susceptibility to sampling techniques indicates future studies targeting larval fish should identify a method of collection suitable for the type of question being asked. Researchers must be conscious of the biases inherent in the sampling method before general trends are extrapolated from results.

The second part of my study (Chapter 3) examined the depth distributions of late stage larval fish. Similar to recent studies on the GBR, my work clearly demonstrated that larval fish have taxon-specific depth preferences. In the San Blas Islands, representatives of the families Acanthuridae, Apogonidae, Gobiidae and Labridae were typically more abundant in deep traps while Gerreidae, Lutjanidae and Pomacentridae were usually more abundant in shallow traps. These patterns were largely consistent with those recorded for both old and very young larval stages of reef fish on the GBR. I suggested that vertical distributions may reflect swimming ability, so that taxa that were relatively poor swimmers were found in surface waters, while species and forms that were more agile were found in deeper water. In Chapter 3, 3 lines of evidence were discussed that support this view: behavioural studies (Stobutzki and Bellwood 1994, Stobutzki 1997), my comparison of active netting and light trap methods (Chapter 2) and ontogenetic changes in the vertical distribution of larval fish (Doherty and Carleton 1997). Simple experimental techniques exist (eg. Stobutzki and Bellwood 1994) that could be used to test my hypothesis. Such studies could be augmented by the direct observation of the behaviour of larval fish around light traps at night and their behaviour in the water column during the day (eg. Leis et al. 1996). These topics would provide a fruitful line of research for future studies in the San Blas Islands.

Summarized, my results provide convincing evidence that the simple assumption that reef fish larvae are passively dispersed over very large distances in the Caribbean (e.g. Roberts 1997) is unlikely to be correct. My results suggest that those species that are potentially poor swimmers occupy planktonic habitats where their dispersal is likely to be restricted and they may be retained near reefs. Those species that do not occupy depth strata where dispersal is limited appear to have highly evolved swimming ability thus may direct their movements within the plankton.

The conclusion that the late stage larvae of reef fishes are unlikely to be passively dispersed plankton is not new. Numerous recent studies on the GBR (reviewed by Doherty and Carleton 1997) suggests that this is the case. My study provides some of the first evidence for active behaviour by late stage larval fishes from reefs in the Caribbean. This has important implications for models of connectivity and for management of reef fish populations. Roberts (1997) suggests that management proposals may have to take into account widespread dispersal between sink and source reefs on the scale of the entire Caribbean region. While long distance dispersal undoubtedly occurs (Victor 1991), the sum of evidence from the my study and recent studies on the GBR suggests that it may not be the norm. In fact, larval fish may act to reduce their dispersal either directly, through active swimming or indirectly, by occupying parts of the water column where they are more likely to be retained around reefs. If this is the case, then management proposals may need to focus on the requirement for numerous small marine reserves that protect only portions of reefs as a means of preserving breeding stocks for the re-supply of populations in the local area. In fact, such management systems may be far easier to implement than those that assume that dispersal is very widespread. In the latter situation, preservation of breeding stocks will require the protection of much larger areas of reef upstream from populations that are exploited (Roberts 1997). This may be extremely difficult if transport of larvae occurs across political boundaries. The need for appropriate management systems of reef fish populations to be implemented in the Caribbean (Roberts 1997) demonstrates that the importance of studies of the behaviour and distribution of larval fish. Given the ongoing degradation of reef communities in the region, this research should be addressed as a matter of urgency. The research described in this thesis is a contribution to this task.

Acknowledgements

I would like to thank everybody who helped in producing this thesis.

First I would like to thank Dave Wilson of the James Cook University in Townsville, whose assistance in the field and lab was of inestimable value. Also thanks for all the help in producing this thesis.

Thanks to Dr. M. Meekan of the Australian Institute of Marine Science who provided valuable constructive criticisms of the manuscript.

Thanks to L. F. M. Fresco of the Rijksuniversiteit Groningen for help with the statistics and Dr. D. R. Robertson as advisor from the Smithsonian Tropical Research Institute.

Thanks to D. Kaiser, M. Wilson, E. Vytopil for helping me out in the field.

I want to thank the Kuna people for the opportunity to sample in their archipelago

The Australian Institute of Marine Science kindly provided the light traps used in this study. This study was supported by a Fellowship from the Smithsonian Tropical Research Institute in Panama. Financial support was also given by grants from Dutch organisations. The Groninger Universiteits Fonds, The Marco Polo fonds, Schuurman Schimmel van Outeren Stichting, and the Dr Hendrik Muller's vaderlandsch fonds all kindly provided the financial means for this study.

Furthermore I would like to thank Dave Wilson for all the mental support I recieved during collecting, lab work and writing.

Ik wil ook graag al mijn vrienden bedanken voor het blijven schrijven en emailen naar me. Korjent van Dijk, heel erg bedankt voor alle steun en aanmoedigingen.

Ook wil ik graag mijn ouders bedanken voor alle geestelijke en financiële steun en vooral omdat ze me hebben laten gaan.

References

- Brogan, M. W. (1994). Two methods of sampling fish larvae over reef: a comparison from the Gulf of California. *Mar. Biol.* 118: 33-44
- Cowen, R. K., Hare, J. A. and Fahay M. P. (1993). Beyond hydrography: can physical processes explain larval fish assemblages within the middle atlantic bight? *Bull. Mar. Sci.* 53(2): 567-587
- Doherty, P., Fowler, T. (1994). An Empirical Test of Recruitment Limitation in a Coral Reef Fish. *Sci.* 263: 935-939
- Doherty, P. J. (1987). Light-traps: selective but useful devices for quantifying the distributions and abundances of larval fishes. *Bull. Mar. Sci.* 41: 423-431
- Doherty, P. J., Williams, D. McB. (1988). The replenishment of coral reef fish populations. *Oceanogr. Mar. Biol. Annu. Rev.* 26: 487-551
- Doherty, P. J., Carleton, J. H. (1997). The distribution and abundance of pelagic juvenile fish near Grub Reef, Central Great Barrier Reef. *Proc. 8th Int. Coral Reef. Sym.* 2: 1155-1160
- Dufour, V., Galzin, R. (1993). Colonization patterns of reef fish larvae to the lagoon at Moorea Island, French Polynesia. *Mar. Ecol. Prog. Ser.* 102: 143-152
- Forward, R. B. jr. (1988). Diel vertical migration: Zooplankton photobiology and behaviour. *Oceanogr. Mar. Biol. Annu. Rev.* 26: 361-393
- Hare, J. A., Cowen, R. K. (1993). Ecological and evolutionary implications of the larval transport and reproductive strategy of bluefish *Pomatomus saltatrix*. *Mar. Ecol. Prog. Ser.* 98: 1-16
- Kaufman, L. *et al.* (1992). A key phase in the recruitment dynamics of coral reef fishes: post-settlement transition. *Env. Biol. Fish.* 34: 109-118
- Kingsford, M. J., Wolanski, E. and Choat, J. H. (1991). Influence of tidally induced fronts and Langmuir circulations on distribution and movements of presettlement fishes around a coral reef. *Mar. Biol.* 109: 167-180
- Leiby, M. M. (1984). Life history and ecology of pelagic fish eggs and larvae. In marine plankton Life cycle strategies. CRC Press Inc. Boca Raton Florida. pp. 121-140
- Leis, J. M. (1986). Vertical and horizontal distribution of fish larvae near coral reefs at Lizard Island, Great Barrier Reef. *Mar. Biol.* 90: 505-516

- Leis, J. M. (1991). Vertical distribution of fish larvae in the Great Barrier Reef Lagoon, Australia. *Mar. Biol.* 109: 157-166
- Leis, J. M. (1994). Coral sea atoll lagoons: closed nurseries for the larvae of a few coral reef fishes. *Bull. Mar. Sci.* 54(1): 206-227
- Leis, J. M., Carson-Ewart, B. M. (1997). In situ swimming speeds of late pelagic larvae of some Indo-Pacific coral-reef fishes. *Mar. Ecol. Prog. Ser.* 159: 165-174
- McCormick, M. I., Molony, B. W. (1992). Effects of feeding history on the growth characteristics of a reef fish at settlement. *Mar. Biol.* 114: 165-173
- McCormick, M. I., Molony, B. W. (1993). Quality of the reef fish *Upeneus tragula* (Mullidae) at settlement: is size a good indicator of condition? *Mar. Ecol. Prog. Ser.* 98: 45-54
- McCormick, M. I., Molony, B. W. (1995). Influence of water temperature during the larval stage on size, age and body condition of a tropical reef fish at settlement. *Mar. Ecol. Prog. Ser.* 118: 59-68
- McCormick, M. I. (1994). Variability in age and size at settlement of the tropical goatfish fish *Upeneus tragula* (Mullidae) in the northern Great Barrier Reef Lagoon. *Mar. Ecol. Prog. Ser.* 103: 1-15
- McCormick, M. I., Makey, L. J. (1997). Post-settlement transition in coral reefs fishes: overlooked complexity in niche shifts. *Mar. Ecol. Prog. Ser.* 153: 247-257
- Roberts, C. M. (1997). Connectivity and Management of Caribbean Coral Reefs. *Sci.* 278: 1454-1457
- Robertson, D. R., Green, D. G. and Victor, B. C. (1988). Temporal coupling of production and recruitment of larvae of a caribbean reef fish. *Ecol.* 69(2): 370-381
- Sale, P. J. (1991). *The Ecology of Fishes on Coral Reefs*. Academic Press, Inc. San Diego California
- Shenker, J. M., Maddox, E. D., Wishinski, E., Pearl, A., Thorrold, S. R., Smith, N., (1993). Onshore transport of settlement-stage Nassau grouper *Epinephelus striatus* and other fishes in Exuma Sound, Bahamas. *Mar. Ecol. Prog. Ser.* 98: 31-43
- Sponaugle, S., Cowen, R. K. (1994). Larval durations and recruitment patterns of two Caribbean gobies (Gobiidae): contrasting early life histories in demersal spawners. *Mar. Biol.* 120: 133-143

- Sponaugle, S., Cowen, R. K. (1996). Larval Supply and Patterns of Recruitment for Two Caribbean Reef Fishes, *Stegastus partitus* and *Acanthurus bahianus*. Mar. Freshwater Res. 47: 433-47
- Sponaugle, S., Cowen, R. K. (1996). Nearshore patterns of coral reef fish larval supply to Barbados, West Indies. Mar. Eco. Prog. Ser. 133: 13-28
- Sponaugle, S., Cowen, R. K. (1997). Early life history traits and recruitment patterns of caribbean wrasses (labridae). Ecol. Mono. 67(2): 177-202
- Stobutzki, I. C (1997). Energetic cost of sustained swimming in the late pelagic stages of reef fishes. Mar. Ecol. Prog. Ser. 152: 249-259
- Stobutzki, I. C., Bellwood, D. R. (1997). Sustained swimming abilities of the late pelagic stages of coral reef fishes. Mar. Ecol. Prog. Ser. 149: 35-41
- Thorrold, S. R. (1992). Evaluating the performance of light-traps for sampling small fish and squid in open waters of the central Great Barrier Reef lagoon. Mar. Eco. Prog. Series 89: 277-285
- Thorrold, S. R., Shenker, J. M., Moijca, R. Jr., Maddox, E. D., Wishinski, E. (1994). Temporal patterns in the larval supply of summer-recruiting reef fishes to Lee Stocking Island, Bahamas. Mar. Ecol. Prog. Ser. 112: 75-86
- Thorrold, S. R., Shenker, J. M., Moijca, R. Jr., Maddox, E. D., Wishinski, E. (1994). Larval supply of shorefishes to nursery habitats around Lee Stocking Island, Bahamas. I. Small-scale distribution patterns. Mar. Biol 118: 555-566
- Thorrold, S. R. Shenker, J. M., Moijca, R. Jr., Maddox, E. D., Wishinski, E. (1994). Larval supply of shorefishes to nursery habitats around Lee Stocking Island, Bahamas. II. Lunar and oceanographic influences. Mar. Biol. 118: 567-578
- Thresher, R. E. (1982). Interoceanic Differences in the Reproduction of Coral-Reef Fish.. Sci. 218: 70-72
- Victor, B. C. (1986). Larval settlement and juvenile mortality in a recruitment-limited coral reef fish population. Eco. Mono. 56(2): 145-160

Appendices

- Appendix A** Identification of reef fish larvae
- Appendix B** Fish larvae caught with during the first cycle for three different methods
- Appendix C** Fish larvae caught with during the second cycle for three different methods
- Appendix D** Fish larvae caught with during the third cycle for three different methods
- Appendix E** Fish larvae caught during the first cycle in the Lagoon
- Appendix F** Fish larvae caught the second cycle in the Lagoon
- Appendix G** Fish larvae caught during the third cycle in the Lagoon
- Appendix H** Fish larvae caught during the first cycle in Sail Rock
- Appendix I** Fish larvae caught during the second cycle in Sail Rock
- Appendix J** Fish larvae caught during the third cycle in Sail Rock

Appendix A

Where possible catches were identified with the help of adult meristics in several works on identification of Caribbean reef fish larvae. Most used references were:

- Bohlke, J.E. and C.C.G. Chaplin (1970) Fishes of the Bahamas and adjacent tropical waters. The Academy of natural sciences of Philadelphia, Livingston publishing company, Wynnewood, Pa.
- Clarke, M. E., Domeier, M. L. and Laroche W.A. (1997) Development of larvae and juveniles of the Mutton snapper (*Lutjanus analis*), Lane snapper (*Lutjanus synagris*) and yellowtail snapper (*Lutjanis chrysurus*). Bull. Mar. Sci. 61(3):511-537
- Human, P. (1996). Reef fish identification - Florida, Caribbean, Bahamas. New World Publications Inc. USA
- Lieske, E. and R. Myers (1994) Coral Reef Fishes, Indo-Pacific & Caribbean. Harper collins publishers, London
- Richards, W.J., K.C. Lindeman, J.L. -Shultz, J.M. Leis, A. Ropke, M.E. Clarke and B.H. Comyns. (1994). Preliminary guide to the identification of the early life history stages of lutjanid fishes of the western central Atlantic. NOAA Tech. Mem. NMFS-SEFSC-345.
- Robins, C.R., G.C. Ray, and J. Douglas (1986) A field guide to Atlantic coast fishes of North America. Houghton Mifflin Company, Boston.

Short description of identification of species which couldn't be identified by means of adult meristics alone. Length is most abundant length found for that category:

Apogonidae (Cardinal fishes)

Small individuals were hard to identify:

Apogonidae sp1

7 mm. Relatively small head. Four ventral melanophores.

Apogonidae sp2

7 mm. Big head. Melanophores ventral, lateral and above eye.

Apogonidae sp3

6 mm. Melanophore anterior and posterior anal fin.

Apogonidae sp4

6 mm. No melanophores. Threads under chin.

Apogonidae sp5

Melanophores ventral.

Blenniidae (Combtooth blennies)

Blenniidae sp2

13 mm Elongate body

Elopidae (Tarpon)

Larvae are not yet transformed but Leptocephali larvae.

Gerreidae (Mojarras)

Larvae were grown out in a aquarium. After more than a week the juveniles were identified as *Eucinostomus melanopterus* by the melanophore on their dorsal fin.

Gobiesocidae (Clingfishes)

Only one species of Gobiesocidae, *Acyrtops beryllina*, occurs in the San Blas Islands (Fish species of San Blas, various autors).

Gobiidae (Gobies)

Gobiidae is a speciose family. Very hard to identify.

Gobiidae sp1

10 mm. No melanophores

Gobiidae sp2

9 mm. Double row (unregular) lateral melanophores. Melanophore anterior pelvic fin.

Gobiidae sp3

9 mm. Melanophore anterior pelvic fin. Three pigment rows posterior eyes on each side. Ventral row melanophores. Dorsal posterior also row melanophores on soft dorsal fin.

Gobiidae sp4

8 mm. Melanophore posterior anal fin. Mark posterior eye.

Gobiidae sp5

10 mm. Regular row ventral melanophores. Brown (spreading) melanophore anterior anal fin. Pigment in upper half eyes and posterior.

Gobiidae sp6

No melanophores. Caudal fin cupped.

Gobiidae sp7 (poss Nes longus)

5 mm. Lots of (spreading) melanophores for instance on dorsal and ventral. Around and in eyes radiating pattern. External melanophores on upper and lower jaw.

Coryphopterus personatus

10 mm. Orange melanophore on cheek. Orange mark on lateral surface caudal peduncle.

Gobionellus saepapallens

Two melanophores on opercle. Five lateral melanophores.

Gobiosoma saucrum

10 mm. Large square areas on head pigmented.

Hemiramphidae (Halfbeaks)

Only one species of halfbeaks, *Hyporhamphus unifasciatus*, occurs in the San Blas Islands (Fish species of San Blas, various authors).

Labridae (Wrasses)

Labridae sp2

8 mm. regular marks ventral, side of body. Dorsal and ventral mark before tailfin. Dot under chin. Forked tail.

Labridae sp3 (poss Halichoeres pictus)

12 mm. Resemblance to *T. bivattatus*. Regular pigment on ventral side. Melanophore on ventral surface anterior to anus. Mark behind side fin. Yellow pigment around eye, underneath eye pinkish.

Labridae sp4

11 mm. Well developed. melanophore anterior to anal fin. Brown pigment above eye. two (faint) marks posterior eye. Two marks ventral on anal fin.

Labridae sp5

8 mm. Slightly yellowish face. High body, not elongate. No melanophores.

Halichoeres bivattatus

Three marks on dorsal, two on anal

H. maculapinna

11 mm. pigment across lateral line (dotted). External melanophores on upper and lower jaw. Triangular melanophore on lateral surface of caudal peduncle.

H. poeyi

Two distinct marks on dorsal fin, two on anal.

Thalassoma bifasciatum

21 dorsal fin count 8 spines, 13 rays. Faint lateral yellow line. melanophore anterior anal fin. Red/yellow shaded head.

Labrisomidae (Scaled blennies)

Malococtenus macropus (rosy blenny) and *M. triangulatus* (saddled blenny) were grown out in aquaria to confirm their identification. *M. triangulatus* already clearly possessed dorsal triangle shaped pigmented areas. *Labrisomus nuchipinnis* (hairy blenny) was very large (>15 mm.) and easy recognizable when caught in the light traps.

Synodontidae (Lizardfishes)

There was only one species lizardfish present in the San Blas Islands. Identification was therefore easy. Larvae were found in totally different stages, ranging from 2 mm. larvae, recognizable by the pigment in the gut area, to transformed late stage larvae of a few centimeters.

Unidentified

Unidentified sp2

17 mm. Elongate. Triangle form melanophore on lateral surface of caudal peduncle. Melanophore under eye. Melanophores on ventral anal fin rays. Melanophore anterior anal fin. Line underneath chin. Sometimes gut visible.

Unidentified sp4

5 mm. Very early stage larvae. Melanophore on ventral surface gut. Big mouth. Melanophore dorsal posterior eyes.

Unidentified sp 5

15 mm. Very elongate. Ventral pigmented line. Eye very low in head.

Unidentified sp6

Large mouth. Two melanophores under chin. Black line radiating from eye. Melanophores ventral posterior.

Unidentified sp7

7 mm. Melanophores anterior and posterior anal fin. Two melanophores anterior pelvic fin. Gut sometimes visible.

Unidentified sp8

Unregular melanophores all over body.

Appendix B

Fish larvae caught during the first cycle for three different methods

| | Kerosene | Fluor-light | Light trap |
|--|----------|-------------|------------|
| Acanthuridae | | | |
| <i>Acanthurus bahianus</i> | 0 | 0 | 0 |
| <i>Acanthurus chirurgus</i> | 0 | 0 | 0 |
| <i>Acanthurus coeruleus</i> | 0 | 0 | 0 |
| Apogonidae | | | |
| <i>Apogon maculatus</i> | 0 | 0 | 0 |
| <i>Apogonid</i> sp. | 0 | 0 | 0 |
| <i>Apogonidae</i> sp. 1 | 0 | 0 | 5 |
| <i>Apogonidae</i> sp. 2 | 0 | 0 | 1 |
| <i>Apogonidae</i> sp. 3 | 0 | 0 | 0 |
| <i>Apogonidae</i> sp. 4 | 0 | 0 | 0 |
| <i>Apogonidae</i> sp. 5 | 0 | 0 | 0 |
| <i>Astrapogon puncticulatus</i> | 0 | 0 | 0 |
| <i>Astrapogon stellatus</i> | 4 | 1 | 6 |
| <i>Phaeoptyx conklini</i> | 0 | 0 | 0 |
| <i>Phaeoptyx pigmentarius</i> | 0 | 0 | 0 |
| Blenniidae | | | |
| <i>Blenniidae</i> sp.2 | 0 | 3 | 0 |
| <i>Ophioblennius atlanticus</i> | 0 | 0 | 0 |
| Bothidae | | | |
| <i>Bothus lunatus</i> | 1 | 0 | 0 |
| <i>Bothus ocellatus</i> | 0 | 0 | 0 |
| Bregmacerotidae | | | |
| <i>Bregmaceros atlanticus</i> | 0 | 0 | 1 |
| Carangidae | | | |
| <i>Chloroscombrus chrysurus</i> | 0 | 0 | 1 |
| <i>Selene vomer</i> | 0 | 0 | 0 |
| Chaetodontidae | | | |
| <i>Chaetodon capistratus</i> | 1 | 0 | 0 |
| <i>Chaetodon striatus</i> | 0 | 0 | 0 |
| Chaenopsidae | | | |
| <i>Hemimblemaria simulus</i> | 0 | 0 | 0 |
| Congridae | | | |
| <i>Heteroconger halis</i> | 0 | 0 | 0 |
| Dactylopteridae | | | |
| <i>Dactylopterus volitans</i> | 0 | 0 | 0 |
| Diodontidae | | | |
| <i>Diodon hystrix</i> | 1 | 0 | 0 |
| Eels | | | |
| <i>Eel</i> var sp. | 4 | 0 | 2 |
| Elopidae | | | |
| <i>Megalops atlanticus</i> | 7 | 6 | 8 |
| Gerreidae | | | |
| <i>Eucinostomus melanopterus</i> | 61 | 74 | 7 |
| Gobiesocidae | | | |
| <i>Acyrtops beryllina</i> | 0 | 3 | 0 |
| Gobiidae | | | |
| <i>Coryphopterus dicrus</i> | 1 | 1 | 24 |
| <i>Coryphopterus glaucofraenum</i> | 0 | 0 | 1 |
| <i>Coryphopterus personatus</i> | 0 | 0 | 3 |
| <i>Gnatholepis thompsoni</i> | 2 | 0 | 16 |
| <i>Gobionellus saepepallens</i> | 0 | 0 | 5 |
| <i>Gobiosoma saucrum</i> | 1 | 0 | 0 |
| <i>Gobiidae</i> sp. 1 | 0 | 0 | 3 |
| <i>Gobiidae</i> sp. 2 | 2 | 1 | 8 |
| <i>Gobiidae</i> sp. 3 | 2 | 0 | 19 |
| <i>Gobiidae</i> sp. 4 | 0 | 0 | 0 |
| <i>Gobiidae</i> sp. 5 | 0 | 0 | 0 |
| <i>Gobiidae</i> sp. 6 | 0 | 0 | 1 |
| <i>Gobiidae</i> sp. 7 (poss. <i>Nes longus</i>) | 0 | 0 | 4 |
| Haemulidae | | | |
| <i>Haemulon aurolineatum</i> | 7 | 5 | 65 |
| <i>Haemulon (striatum)</i> | 0 | 0 | 0 |
| Hemiramphidae | | | |
| <i>Hyporhamphus unifasciatus</i> | 0 | 0 | 0 |
| Holocentridae | | | |
| <i>Holocentrus vexillarius</i> | 0 | 0 | 0 |

| | Kerosene | Fluor-light | Light trap |
|---|------------|-------------|-------------|
| Labridae | | | |
| <i>Halichoeres bivattatus</i> | 0 | 0 | 3 |
| <i>Halichoeres poeyi</i> | 0 | 0 | 0 |
| <i>Labridae</i> sp. 2 | 0 | 2 | 1 |
| <i>Labridae</i> sp. 3 (poss. <i>H. pictus</i>) | 1 | 4 | 1 |
| <i>Labridae</i> sp. 4 | 0 | 2 | 0 |
| <i>Labridae</i> sp. 5 | 0 | 3 | 1 |
| <i>Thalassoma bifasciatum</i> | 15 | 12 | 6 |
| Labrisomidae | | | |
| <i>Labrisomus nuchipinnis</i> | 0 | 0 | 0 |
| <i>Malacoctenus macropus</i> | 41 | 42 | 13 |
| <i>Malacoctenus triangulatus</i> | 0 | 0 | 0 |
| Lutjanidae | | | |
| <i>Lutjanus apodus</i> | 0 | 0 | 0 |
| <i>Lutjanus buccanella</i> | 0 | 0 | 0 |
| <i>Lutjanus chrysurus</i> | 0 | 0 | 0 |
| <i>Lutjanus mahogani</i> | 0 | 0 | 0 |
| Monacanthidae | | | |
| <i>Monacanthus setifer</i> | 14 | 1 | 8 |
| Mullidae | | | |
| <i>Pseudupeneus maculatus</i> | 0 | 0 | 0 |
| Ostraciidae | | | |
| <i>Lactophrys polygona</i> | 0 | 0 | 1 |
| Polyneimidae | | | |
| <i>Polydactylus virginicus</i> | 0 | 0 | 0 |
| Pomacentridae | | | |
| <i>Siegastes dorsopunicans</i> | 1 | 0 | 1 |
| <i>Siegastes leucostictus</i> | 0 | 0 | 0 |
| <i>Siegastes planifrons</i> | 0 | 3 | 0 |
| <i>Siegastes partitus</i> | 0 | 0 | 0 |
| <i>Siegastes variabilis</i> | 0 | 0 | 0 |
| <i>Microspathodon chrysurus</i> | 0 | 0 | 0 |
| Priacanthidae | | | |
| <i>Priacanthus cruentatus</i> | 0 | 0 | 0 |
| Scombridae | | | |
| <i>Scomberomorus regalis</i> | 0 | 1 | 0 |
| Scorpaenidae | | | |
| <i>Scorpaena plumieri</i> | 0 | 1 | 1 |
| Serranidae | | | |
| <i>Serranidae</i> sp. 1 | 0 | 0 | 0 |
| Sphyraenidae | | | |
| <i>Sphyraena barracuda</i> | 0 | 1 | 0 |
| Syngnathidae | | | |
| <i>Cosmocampus elucens (M.crinitus?)</i> | 0 | 0 | 0 |
| Synodontidae | | | |
| <i>Synodus intermedius</i> | 12 | 6 | 20 |
| Tetraodontidae | | | |
| <i>Chilomycterus</i> sp. | 0 | 1 | 0 |
| <i>Sphaeroides spengleri</i> | 0 | 0 | 0 |
| Clupeoids | | | |
| <i>Anchoa lyolepis (Engraulidae)</i> | 48 | 69 | 2187 |
| <i>Jenkinsia lamprotaenia (Clupeidae)</i> | 52 | 106 | 167 |
| <i>Atherinomorus stipes (Atherinidae)</i> | 148 | 313 | 71 |
| Unidentified | | | |
| Damaged | 0 | 0 | 1 |
| Early stage larvae | 0 | 0 | 0 |
| Unidentified sp. 2 | 0 | 0 | 4 |
| Unidentified sp. 4 | 0 | 0 | 0 |
| Unidentified sp. 5 | 0 | 0 | 0 |
| Unidentified sp. 6 | 0 | 2 | 12 |
| Unidentified sp. 7 | 1 | 0 | 0 |
| Unidentified sp. 8 | 0 | 0 | 3 |
| Unidentified sp. 8A | 0 | 0 | 65 |
| Total #fish/station | 431 | 666 | 2766 |
| Total fish without sardines | 183 | 178 | 341 |

Appendix C

Fish larvae caught during the second cycle for three different methods

| | Kerosene | Fluor-light | Light trap |
|--|----------|-------------|------------|
| Acanthuridae | | | |
| <i>Acanthurus bahianus</i> | 0 | 0 | 0 |
| <i>Acanthurus chirurgus</i> | 0 | 0 | 0 |
| <i>Acanthurus coeruleus</i> | 0 | 0 | 0 |
| Apogonidae | 1 | 0 | 0 |
| <i>Apogon maculatus</i> | 0 | 0 | 0 |
| <i>Apogonid</i> sp. | 0 | 0 | 0 |
| <i>Apogonidae</i> sp. 1 | 0 | 0 | 2 |
| <i>Apogonidae</i> sp. 2 | 0 | 0 | 0 |
| <i>Apogonidae</i> sp. 3 | 0 | 0 | 0 |
| <i>Apogonidae</i> sp. 4 | 0 | 0 | 0 |
| <i>Apogonidae</i> sp. 5 | 0 | 0 | 2 |
| <i>Astrapogon puncticulatus</i> | 0 | 0 | 0 |
| <i>Astrapogon stellatus</i> | 0 | 0 | 3 |
| <i>Phaeoptyx conklini</i> | 0 | 0 | 2 |
| <i>Phaeoptyx pigmentarius</i> | 1 | 2 | 7 |
| Blenniidae | | | |
| <i>Blenniidae</i> sp.2 | 0 | 0 | 2 |
| <i>Ophioblennius atlanticus</i> | 0 | 0 | 0 |
| Bothidae | | | |
| <i>Bothus lunatus</i> | 0 | 0 | 0 |
| <i>Bothus ocellatus</i> | 0 | 0 | 0 |
| Bregmacerotidae | | | |
| <i>Bregmaceres atlanticus</i> | 1 | 0 | 1 |
| Carangidae | | | |
| <i>Chloroscombrus chrysurus</i> | 0 | 0 | 0 |
| <i>Selene vomer</i> | 0 | 0 | 0 |
| Chaetodontidae | | | |
| <i>Chaetodonton capistratus</i> | 0 | 0 | 0 |
| <i>Chaetodonton striatus</i> | 0 | 0 | 0 |
| Chaenopsidae | | | |
| <i>Hemimblemaria simulus</i> | 0 | 1 | 1 |
| Congridae | | | |
| <i>Heteroconger halis</i> | 0 | 0 | 0 |
| Dactylopteridae | | | |
| <i>Dactylopterus volitans</i> | 0 | 0 | 0 |
| Diodontidae | | | |
| <i>Diodon hystrix</i> | 1 | 0 | 0 |
| Eels | | | |
| <i>Eel</i> var sp. | 0 | 1 | 0 |
| Elopidae | | | |
| <i>Megalops atlanticus</i> | 1 | 1 | 6 |
| Gerreidae | | | |
| <i>Eucinostomus melanopterus</i> | 8 | 13 | 10 |
| Gobiesocidae | | | |
| <i>Acyrtops beryllina</i> | 0 | 0 | 0 |
| Gobiidae | | | |
| <i>Coryphopterus dicrus</i> | 0 | 0 | 81 |
| <i>Coryphopterus glaucofraenum</i> | 0 | 0 | 0 |
| <i>Coryphopterus personatus</i> | 0 | 0 | 0 |
| <i>Gnatholepis thompsoni</i> | 0 | 1 | 8 |
| <i>Gobionellus saepepallens</i> | 1 | 0 | 0 |
| <i>Gobiosoma saucerum</i> | 0 | 0 | 0 |
| <i>Gobiidae</i> sp. 1 | 0 | 0 | 0 |
| <i>Gobiidae</i> sp. 2 | 0 | 0 | 35 |
| <i>Gobiidae</i> sp. 3 | 0 | 1 | 15 |
| <i>Gobiidae</i> sp. 4 | 0 | 0 | 0 |
| <i>Gobiidae</i> sp. 5 | 0 | 0 | 8 |
| <i>Gobiidae</i> sp. 6 | 0 | 0 | 6 |
| <i>Gobiidae</i> sp. 7 (poss. <i>Nes longus</i>) | 0 | 0 | 18 |
| Haemulidae | | | |
| <i>Haemulon aurolineatum</i> | 0 | 1 | 0 |
| <i>Haemulon (striatum?)</i> | 1 | 1 | 0 |
| Hemiramphidae | | | |
| <i>Hyporhamphus unifasciatus</i> | 0 | 1 | 0 |
| Holocentridae | | | |
| <i>Holocentrus vexillarius</i> | 0 | 0 | 0 |

| | Kerosene | Fluor-light | Light trap |
|---|----------|-------------|------------|
| Labridae | | | |
| <i>Halichoeres bivittatus</i> | 0 | 0 | 0 |
| <i>Halichoeres poeyi</i> | 0 | 1 | 0 |
| <i>Labridae</i> sp. 2 | 0 | 0 | 34 |
| <i>Labridae</i> sp. 3 (poss. <i>H. pictus</i>) | 0 | 0 | 0 |
| <i>Labridae</i> sp. 4 | 0 | 0 | 0 |
| <i>Labridae</i> sp. 5 | 0 | 0 | 0 |
| <i>Thalassoma bifasciatum</i> | 2 | 0 | 1 |
| Labrisomidae | | | |
| <i>Labrisomus nuchipinnis</i> | 0 | 1 | 0 |
| <i>Malacoctenus macropus</i> | 29 | 14 | 24 |
| <i>Malacoctenus triangulatus</i> | 0 | 0 | 0 |
| Lutjanidae | | | |
| <i>Lutjanus apodus</i> | 0 | 0 | 0 |
| <i>Lutjanus buccanella</i> | 0 | 0 | 0 |
| <i>Lutjanus chrysurus</i> | 0 | 0 | 0 |
| <i>Lutjanus mahogani</i> | 0 | 0 | 0 |
| Monacanthidae | | | |
| <i>Monacanthus setifer</i> | 12 | 11 | 16 |
| Mullidae | | | |
| <i>Pseudupeneus maculatus</i> | 0 | 0 | 0 |
| Ostraciidae | | | |
| <i>Lactophrys polygonia</i> | 0 | 0 | 0 |
| Polynemidae | | | |
| <i>Polydactylus virginicus</i> | 0 | 0 | 0 |
| Pomacentridae | | | |
| <i>Stegastes dorsopunicans</i> | 1 | 0 | 0 |
| <i>Stegastes leucostictus</i> | 0 | 0 | 0 |
| <i>Stegastes planifrons</i> | 0 | 0 | 0 |
| <i>Stegastes partitus</i> | 0 | 0 | 0 |
| <i>Stegastes variabilis</i> | 0 | 0 | 0 |
| <i>Microspathodon chrysurus</i> | 0 | 0 | 0 |
| Priacanthidae | | | |
| <i>Priacanthus cruentatus</i> | 0 | 0 | 0 |
| Scombridae | | | |
| <i>Scomberomorus regalis</i> | 0 | 0 | 1 |
| Scorpaenidae | | | |
| <i>Scorpaena plumieri</i> | 0 | 0 | 0 |
| Serranidae | | | |
| <i>Serranidae</i> sp. 1 | 0 | 1 | 2 |
| Sphyracidae | | | |
| <i>Sphyracna barracuda</i> | 0 | 0 | 0 |
| Syngnathidae | | | |
| <i>Cosmocampus elucens (M.crinatus?)</i> | 0 | 12 | 0 |
| Synodontidae | | | |
| <i>Synodus intermedius</i> | 0 | 0 | 7 |
| Tetraodontidae | | | |
| <i>Chilomycterus</i> sp. | 0 | 0 | 0 |
| <i>Sphaeroides spengleri</i> | 0 | 0 | 0 |
| Clupeoids | | | |
| <i>Anchoa lyolepis (Engraulidae)</i> | 1 | 0 | 7 |
| <i>Jenkinsia lamprotaenia (Clupeidae)</i> | 45 | 10 | 73 |
| <i>Atherinomorus stipes (Atherinidae)</i> | 37 | 135 | 0 |
| Unidentified | 0 | 0 | 0 |
| Damaged | 0 | 0 | 0 |
| Early stage larvae | 0 | 0 | 0 |
| Unidentified sp. 2 | 0 | 0 | 6 |
| Unidentified sp. 4 | 0 | 0 | 0 |
| Unidentified sp. 5 | 0 | 0 | 0 |
| Unidentified sp. 6 | 0 | 1 | 52 |
| Unidentified sp. 7 | 0 | 0 | 0 |
| Unidentified sp. 8 | 0 | 0 | 0 |
| Unidentified sp. 8A | 0 | 0 | 0 |
| Total #fish/station | 142 | 209 | 430 |
| Total fish without sardines | 59 | 64 | 350 |

Appendix D

Fish larvae caught during the third cycle for three different methods

| | Kerosene | Fluor-light | Light trap |
|---|----------|-------------|------------|
| Acanthuridae | | | |
| <i>Acanthurus bahianus</i> | 0 | 0 | 0 |
| <i>Acanthurus chirurgus</i> | 0 | 0 | 4 |
| <i>Acanthurus coeruleus</i> | 0 | 0 | 0 |
| Apogonidae | | | |
| <i>Apogon maculatus</i> | 0 | 0 | 0 |
| Apogonid sp. | 0 | 0 | 0 |
| Apogonidae sp. 1 | 0 | 0 | 0 |
| Apogonidae sp. 2 | 0 | 0 | 0 |
| Apogonidae sp. 3 | 0 | 0 | 0 |
| Apogonidae sp. 4 | 0 | 0 | 0 |
| Apogonidae sp. 5 | 0 | 0 | 0 |
| <i>Astrapogon puncticulatus</i> | 0 | 0 | 0 |
| <i>Astrapogon stellatus</i> | 0 | 0 | 0 |
| <i>Phaeoptyx conklini</i> | 0 | 0 | 0 |
| <i>Phaeoptyx pigmentarius</i> | 0 | 0 | 0 |
| Blenniidae | | | |
| Blenniidae sp.2 | 0 | 1 | 1 |
| <i>Ophioblennius atlanticus</i> | 0 | 0 | 1 |
| Bothidae | | | |
| <i>Bothus lunatus</i> | 0 | 0 | 0 |
| <i>Bothus ocellatus</i> | 0 | 0 | 1 |
| Bregmacerotidae | | | |
| <i>Bregmaceros atlanticus</i> | 0 | 1 | 2 |
| Carangidae | | | |
| <i>Chloroscombrus chrysurus</i> | 0 | 0 | 0 |
| <i>Selene vomer</i> | 0 | 0 | 0 |
| Chaetodontidae | | | |
| <i>Chaetodonton capistratus</i> | 0 | 1 | 0 |
| <i>Chaetodonton striatus</i> | 0 | 0 | 0 |
| Chaenopsidae | | | |
| <i>Hemiblemnia simulus</i> | 0 | 0 | 0 |
| Congridae | | | |
| <i>Heteroconger halis</i> | 0 | 0 | 0 |
| Dactylopteridae | | | |
| <i>Dactylopterus volitans</i> | 0 | 1 | 0 |
| Diodontidae | | | |
| <i>Diodon hystrix</i> | 1 | 0 | 0 |
| Eels | | | |
| Eel var sp. | 0 | 0 | 0 |
| Elopidae | | | |
| <i>Megalops atlanticus</i> | 1 | 0 | 2 |
| Gerreidae | | | |
| <i>Eucinostomus melanopterus</i> | 11 | 23 | 1 |
| Gobiesocidae | | | |
| <i>Acyrtops beryllina</i> | 0 | 0 | 0 |
| Gobiidae | | | |
| <i>Coryphopterus dicrus</i> | 0 | 3 | 0 |
| <i>Coryphopterus glaucofraenum</i> | 0 | 0 | 0 |
| <i>Coryphopterus personatus</i> | 0 | 0 | 0 |
| <i>Gnatholepis thompsoni</i> | 1 | 1 | 0 |
| <i>Gobionellus saepepallens</i> | 0 | 0 | 0 |
| <i>Gobiosoma saucrum</i> | 0 | 0 | 0 |
| Gobiidae sp. 1 | 0 | 0 | 0 |
| Gobiidae sp. 2 | 2 | 0 | 0 |
| Gobiidae sp. 3 | 0 | 0 | 0 |
| Gobiidae sp. 4 | 0 | 0 | 0 |
| Gobiidae sp. 5 | 0 | 1 | 0 |
| Gobiidae sp. 6 | 2 | 0 | 0 |
| Gobiidae sp. 7 (poss. <i>Nes longus</i>) | 0 | 0 | 0 |
| Haemulidae | | | |
| <i>Haemulon aurolineatum</i> | 3 | 2 | 0 |
| <i>Haemulon (striatum?)</i> | 0 | 0 | 0 |
| Hemiramphidae | | | |
| <i>Hyporhamphus unifasciatus</i> | 0 | 0 | 0 |
| Holocentridae | | | |
| <i>Holocentrus vexillarius</i> | 0 | 0 | 0 |

| | Kerosene | Fluor-light | Light trap |
|---|------------|-------------|------------|
| Labridae | 6 | 0 | 0 |
| <i>Halichoeres bivittatus</i> | 0 | 0 | 0 |
| <i>Halichoeres poeyi</i> | 0 | 0 | 0 |
| Labridae sp. 2 | 0 | 0 | 0 |
| Labridae sp. 3 (poss. <i>H. pictus</i>) | 0 | 0 | 0 |
| Labridae sp. 4 | 0 | 0 | 0 |
| Labridae sp. 5 | 0 | 2 | 0 |
| <i>Thalassoma bifasciatum</i> | 9 | 9 | 0 |
| Labrisomidae | | | |
| <i>Labrisomus nuchipinnis</i> | 0 | 1 | 0 |
| <i>Malacoctenus macropus</i> | 0 | 5 | 1 |
| <i>Malacoctenus triangulatus</i> | 0 | 0 | 0 |
| Lutjanidae | | | |
| <i>Lutjanus apodus</i> | 0 | 0 | 0 |
| <i>Lutjanus buccanella</i> | 0 | 0 | 0 |
| <i>Lutjanus chrysurus</i> | 0 | 0 | 0 |
| <i>Lutjanus mahogani</i> | 0 | 0 | 0 |
| Monacanthidae | | | |
| <i>Monacanthus setifer</i> | 1 | 0 | 3 |
| Mullidae | | | |
| <i>Pseudupeneus maculatus</i> | 0 | 0 | 0 |
| Ostraciidae | | | |
| <i>Lactophrys polygonia</i> | 0 | 0 | 0 |
| Polyneimidae | | | |
| <i>Polydactylus virginicus</i> | 0 | 0 | 0 |
| Pomacentridae | | | |
| <i>Stegastes dorsopunicans</i> | 0 | 0 | 0 |
| <i>Stegastes leucostictus</i> | 0 | 0 | 0 |
| <i>Stegastes planifrons</i> | 0 | 0 | 0 |
| <i>Stegastes partitus</i> | 0 | 0 | 0 |
| <i>Stegastes variabilis</i> | 0 | 0 | 0 |
| <i>Microspathodon chrysurus</i> | 0 | 0 | 0 |
| Priacanthidae | | | |
| <i>Priacanthus cruentatus</i> | 0 | 0 | 0 |
| Scombridae | | | |
| <i>Scomberomorus regalis</i> | 0 | 0 | 0 |
| Scorpaenidae | | | |
| <i>Scorpaena plumieri</i> | 0 | 0 | 0 |
| Serranidae | | | |
| Serranidae sp. 1 | 0 | 0 | 1 |
| Sphyraenidae | | | |
| <i>Sphyraena barracuda</i> | 0 | 0 | 0 |
| Sygnathidae | | | |
| <i>Cosmocampus elucens (M.crinitus?)</i> | 0 | 0 | 0 |
| Synodontidae | | | |
| <i>Synodus intermedius</i> | 3 | 0 | 2 |
| Tetraodontidae | | | |
| <i>Chilomycterus</i> sp | 0 | 0 | 0 |
| <i>Sphaeroides spengleri</i> | 0 | 0 | 0 |
| Clupeoids | | | |
| <i>Anchoa lyolepis (Engraulidae)</i> | 272 | 13 | 53 |
| <i>Jenkinsia lamprotaenia (Clupeidae)</i> | 13 | 35 | 41 |
| <i>Atherinomorus stipes (Atherinidae)</i> | 223 | 438 | 1 |
| Unidentified | | | |
| Damaged | 0 | 0 | 0 |
| Early stage larvae | 0 | 0 | 0 |
| Unidentified sp. 2 | 0 | 0 | 0 |
| Unidentified sp. 4 | 0 | 0 | 0 |
| Unidentified sp. 5 | 0 | 0 | 0 |
| Unidentified sp. 6 | 0 | 0 | 0 |
| Unidentified sp. 7 | 0 | 0 | 0 |
| Unidentified sp. 8 | 0 | 0 | 0 |
| Unidentified sp. 8A | 0 | 0 | 0 |
| Total #fish/station | 548 | 538 | 114 |
| Total fish without sardines | 40 | 52 | 19 |

| | Traps | |
|---|---------|------|
| | Shallow | Deep |
| Acanthuridae | | |
| <i>Acanthurus bahianus</i> | 0 | 0 |
| <i>Acanthurus chirurgus</i> | 0 | 2 |
| <i>Acanthurus coeruleus</i> | 1 | 1 |
| Apogonidae | | |
| <i>Apogon maculatus</i> | 0 | 0 |
| <i>Apogon planifrons</i> | 0 | 0 |
| Apogonid sp. | 0 | 1 |
| Apogonidae sp. 1 | 0 | 1 |
| Apogonidae sp. 2 | 0 | 0 |
| Apogonidae sp. 3 | 0 | 0 |
| Apogonidae sp. 4 | 0 | 0 |
| Apogonidae sp. 5 | 0 | 0 |
| <i>Astrapogon puncticulatus</i> | 0 | 0 |
| <i>Astrapogon stellatus</i> | 0 | 0 |
| <i>Phaeoptyx conklini</i> | 0 | 3 |
| <i>Phaeoptyx pigmentarius</i> | 0 | 0 |
| Blenniidae | | |
| Blenniidae sp.2 | 0 | 0 |
| <i>Ophioblennius atlanticus</i> | 2 | 0 |
| <i>Malocotenus macropus</i> | 0 | 2 |
| Bothidae | | |
| <i>Bothus lunatus</i> | 0 | 0 |
| <i>Bothus ocellatus</i> | 0 | 0 |
| Bregmacerotidae | | |
| <i>Bregmaceros atlanticus</i> | 1 | 0 |
| Carangidae | | |
| <i>Chloroscombrus chrysurus</i> | 5 | 1 |
| <i>Decapterus</i> sp. | 0 | 0 |
| <i>Selene vomer</i> | 0 | 1 |
| Chaetodontidae | | |
| <i>Chaetodon capistratus</i> | 0 | 0 |
| <i>Chaetodon striatus</i> | 0 | 0 |
| Chaenopsidae | | |
| <i>Hemimblemaria simulus</i> | 0 | 0 |
| Congridae | | |
| <i>Heteroconger halis</i> | 0 | 0 |
| Dactylopteridae | | |
| <i>Dactylopterus volitans</i> | 0 | 0 |
| Diodontidae | | |
| <i>Diodon hystrix</i> | 0 | 0 |
| Eels | | |
| Eel var sp. | 0 | 1 |
| Elopidae | | |
| <i>Megalops atlanticus</i> | 8 | 2 |
| Gerreidae | | |
| <i>Eucinostomus melanopterus</i> | 61 | 0 |
| Gobiesocidae | | |
| <i>Acyrtops beryllina</i> | 0 | 0 |
| Gobiidae | | |
| <i>Coryphopterus dicrus</i> | 0 | 2 |
| <i>Coryphopterus glaucofraenum</i> | 0 | 0 |
| <i>Coryphopterus personatus</i> | 0 | 0 |
| <i>Gnatholepis thompsoni</i> | 0 | 0 |
| <i>Gobiosoma saucrum</i> | 0 | 0 |
| Gobiidae sp. 1 | 0 | 0 |
| Gobiidae sp. 2 | 0 | 0 |
| Gobiidae sp. 3 | 0 | 0 |
| Gobiidae sp. 4 | 0 | 0 |
| Gobiidae sp. 5 | 0 | 0 |
| Gobiidae sp. 6 | 0 | 0 |
| Gobiidae sp. 7 (poss. <i>Nes longus</i>) | 0 | 0 |
| Haemulidae | | |
| <i>Haemulon aurolineatum</i> | 1 | 0 |
| Hemiramphidae | | |
| <i>Hyporhamphus unifasciatus</i> | 0 | 0 |
| Holocentridae | | |
| <i>Holocentrus vexillarius</i> | 0 | 6 |

| | Traps | |
|---|---------|-------|
| | Shallow | Deep |
| Labridae | 1 | 0 |
| <i>Halichoeres bivattatus</i> | 0 | 0 |
| <i>Halichoeres garnoti</i> | 0 | 0 |
| <i>Halichoeres maculipinna</i> | 0 | 0 |
| <i>Halichoeres poeyi</i> | 0 | 0 |
| Labridae sp. 2 | 0 | 1 |
| Labridae sp. 3 (poss. <i>H. pictus</i>) | 0 | 0 |
| Labridae sp. 4 | 0 | 0 |
| Labridae sp. 5 | 0 | 0 |
| <i>Thalassoma bifasciatum</i> | 3 | 1 |
| Labrisomidae | | |
| <i>Labrisomus nuchipinnis</i> | 0 | 1 |
| <i>Malacotenus macropus</i> | 0 | 0 |
| <i>Malacotenus triangulatus</i> | 0 | 0 |
| Lutjanidae | | |
| <i>Lutjanus apodus</i> | 2 | 0 |
| <i>Lutjanus buccanella</i> | 0 | 0 |
| <i>Lutjanus chrysurus</i> | 0 | 0 |
| <i>Lutjanus mahogani</i> | 1 | 3 |
| Monacanthidae | | |
| <i>Monacanthus setifer</i> | 1 | 0 |
| Mullidae | | |
| <i>Pseudopomus maculatus</i> | 0 | 0 |
| Polynemidae | | |
| <i>Polydactylus virginicus</i> | 0 | 0 |
| Pomacanthidae | | |
| <i>Pomacanthus arcuatus</i> | 0 | 0 |
| Pomacentridae | | |
| <i>Abudefduf saxatilis</i> | 0 | 0 |
| <i>Stegastes dorsopunicans</i> | 31 | 2 |
| <i>Stegastes leucostictus</i> | 4 | 0 |
| <i>Stegastes planifrons</i> | 100 | 2 |
| <i>Stegastes partitus</i> | 3 | 0 |
| <i>Stegastes variabilis</i> | 2 | 0 |
| <i>Microspathodon chrysurus</i> | 1 | 0 |
| Priacanthidae | | |
| <i>Priacanthus cruentatus</i> | 0 | 1 |
| Scombridae | | |
| <i>Scomberomorus regalis</i> | 2 | 4 |
| Scorpaenidae | | |
| Serranidae | | |
| <i>Epinephelus striatus</i> | 0 | 5 |
| Serranidae sp. 1 | 0 | 0 |
| Sphyraenidae | | |
| <i>Sphyraena barracuda</i> | 0 | 0 |
| Sygnathidae | | |
| <i>Cosmocampus elucens (M. crinitus?)</i> | 0 | 0 |
| Synodontidae | | |
| <i>Synodus intermedius</i> | 75 | 68 |
| Tetraodontidae | | |
| <i>Sphoeroides spengleri</i> | 1 | 0 |
| Trichiuridae | | |
| <i>Trichiurus lepturus</i> | 0 | 0 |
| | 0 | 0 |
| Clupeoids | | |
| <i>Anchoa lyolepis</i> (Engraulidae) | 3425 | 9679 |
| <i>Jenkinsia lamprotaenia</i> (Clupeidae) | 6379 | 4409 |
| <i>Atherinomorinus stipes</i> (Atherinidae) | 4 | 0 |
| Unidentified | 5 | 0 |
| Damaged | 0 | 0 |
| Early stage larvae | 0 | 0 |
| Unidentified sp. 2 | 0 | 0 |
| Unidentified sp. 4 | 0 | 1 |
| Unidentified sp. 5 | 0 | 1 |
| Unidentified sp. 6 | 0 | 0 |
| Total #fish/station | 10119 | 14201 |
| Total fish without sardines | 311 | 113 |

| | Traps | |
|---|---------|------|
| | Shallow | Deep |
| Acanthuridae | | |
| <i>Acanthurus bahianus</i> | 0 | 1 |
| <i>Acanthurus chirurgus</i> | 5 | 16 |
| <i>Acanthurus coeruleus</i> | 0 | 0 |
| Apogonidae | | |
| <i>Apogon maculatus</i> | 1 | 0 |
| <i>Apogon planifrons</i> | 0 | 0 |
| Apogonid sp. | 0 | 0 |
| Apogonidae sp. 1 | 0 | 0 |
| Apogonidae sp. 2 | 3 | 0 |
| Apogonidae sp. 3 | 0 | 0 |
| Apogonidae sp. 4 | 0 | 0 |
| Apogonidae sp. 5 | 0 | 0 |
| <i>Astrapogon puncticulatus</i> | 0 | 0 |
| <i>Astrapogon stellatus</i> | 0 | 0 |
| <i>Phaeoptyx conklini</i> | 0 | 0 |
| <i>Phaeoptyx pigmentarius</i> | 2 | 0 |
| Blenniidae | | |
| Blenniidae sp.2 | 0 | 0 |
| <i>Ophioblennius atlanticus</i> | 0 | 0 |
| <i>Malococentrus macropus</i> | 2 | 1 |
| Bothidae | | |
| <i>Bothus lunatus</i> | 3 | 0 |
| <i>Bothus ocellatus</i> | 0 | 0 |
| Bregmacerotidae | 0 | 0 |
| <i>Bregmaceros atlanticus</i> | | |
| Carangidae | 0 | 0 |
| <i>Chloroscombrus chrysurus</i> | 8 | 2 |
| <i>Decapterus</i> sp. | 0 | 0 |
| <i>Selene vomer</i> | 0 | 0 |
| Chaetodontidae | | |
| <i>Chaetodon capistratus</i> | 0 | 3 |
| <i>Chaetodon striatus</i> | 1 | 1 |
| Chaenopsidae | | |
| <i>Hemimblemaria simulus</i> | 0 | 0 |
| Congridae | | |
| <i>Heteroconger halis</i> | 0 | 0 |
| Dactylopteridae | | |
| <i>Dactylopterus volitans</i> | 1 | 0 |
| Diodontidae | | |
| <i>Diodon hystrix</i> | 0 | 0 |
| Eels | | |
| Eel var sp. | 0 | 1 |
| Elopidae | | |
| <i>Megalops atlanticus</i> | 2 | 3 |
| Gerreidae | | |
| <i>Eucinostomus melanopterus</i> | 108 | 2 |
| Gobiesocidae | | |
| <i>Acyrtops beryllina</i> | 0 | 0 |
| Gobiidae | 0 | 4 |
| <i>Coryphopterus dicrus</i> | 0 | 1 |
| <i>Coryphopterus glaucofraenum</i> | 0 | 0 |
| <i>Coryphopterus personatus</i> | 0 | 0 |
| <i>Gnatholepis thompsoni</i> | 1 | 11 |
| <i>Gobiosoma saucrum</i> | 0 | 0 |
| Gobiidae sp. 1 | 0 | 0 |
| Gobiidae sp. 2 | 1 | 2 |
| Gobiidae sp. 3 | 0 | 0 |
| Gobiidae sp. 4 | 0 | 0 |
| Gobiidae sp. 5 | 0 | 0 |
| Gobiidae sp. 6 | 0 | 0 |
| Gobiidae sp. 7 (poss. <i>Nes longus</i>) | 0 | 0 |
| Haemulidae | 4 | 0 |
| <i>Haemulon aurolineatum</i> | 1 | 0 |
| Hemiramphidae | | |
| <i>Hyporhamphus unifasciatus</i> | 0 | 0 |
| Holocentridae | | |
| <i>Holocentrus vexillarius</i> | 0 | 0 |

| | Traps | |
|---|---------|------|
| | Shallow | Deep |
| Labridae | 0 | 1 |
| <i>Halichoeres bivattatus</i> | 0 | 0 |
| <i>Halichoeres garnoti</i> | 0 | 0 |
| <i>Halichoeres maculipinna</i> | 0 | 0 |
| <i>Halichoeres poeyi</i> | 0 | 0 |
| Labridae sp. 2 | 3 | 0 |
| Labridae sp. 3 (poss. <i>H. pictus</i>) | 0 | 0 |
| Labridae sp. 4 | 0 | 0 |
| Labridae sp. 5 | 0 | 1 |
| <i>Thalassoma bifasciatum</i> | 4 | 1 |
| Labrisomidae | | |
| <i>Labrisomus nuchipinnis</i> | 0 | 2 |
| <i>Malacocentrus macropus</i> | 0 | 0 |
| <i>Malacocentrus triangulatus</i> | 0 | 0 |
| Lutjanidae | | |
| <i>Lutjanus apodus</i> | 0 | 0 |
| <i>Lutjanus buccanella</i> | 0 | 0 |
| <i>Lutjanus chrysurus</i> | 0 | 0 |
| <i>Lutjanus mahogani</i> | 1 | 4 |
| Monacanthidae | | |
| <i>Monacanthus setifer</i> | 2 | 0 |
| Mullidae | | |
| <i>Pseudopeneus maculatus</i> | 0 | 0 |
| Polynemidae | | |
| <i>Polydactylus virginicus</i> | 0 | 0 |
| Pomacanthidae | | |
| <i>Pomacanthus arcuatus</i> | 0 | 0 |
| Pomacentridae | | |
| <i>Abudefduf saxatilis</i> | 0 | 0 |
| <i>Stegastes dorsopunicans</i> | 4 | 3 |
| <i>Stegastes leucostictus</i> | 0 | 0 |
| <i>Stegastes planifrons</i> | 34 | 16 |
| <i>Stegastes partitus</i> | 1 | 0 |
| <i>Stegastes variabilis</i> | 1 | 5 |
| <i>Microspathodon chrysurus</i> | 0 | 0 |
| Priacanthidae | | |
| <i>Priacanthus cruentatus</i> | 0 | 0 |
| Scombridae | | |
| <i>Scomberomorus regalis</i> | 1 | 0 |
| Scorpaenidae | 0 | 0 |
| Serranidae | | |
| <i>Epinephelus striatus</i> | 0 | 0 |
| Serranidae sp. 1 | 1 | 0 |
| Sphyraenidae | | |
| <i>Sphyraena barracuda</i> | 0 | 0 |
| Sygnathidae | | |
| <i>Cosmocampus elucens (M.crinitus?)</i> | 0 | 0 |
| Synodontidae | | |
| <i>Synodus intermedius</i> | 4 | 21 |
| Tetraodontidae | | |
| <i>Sphoeroides spengleri</i> | 0 | 0 |
| Trichiuridae | | |
| <i>Trichiurus lepturus</i> | 0 | 0 |
| | 0 | 0 |
| Clupeoids | | |
| <i>Anchoa lyolepis</i> (Engraulidae) | 281 | 588 |
| <i>Jenkinsia lamprotaenia</i> (Clupeidae) | 832 | 251 |
| <i>Atherinomorus stipes</i> (Atherinidae) | 3 | 5 |
| Unidentified | | |
| Damaged | 22 | 3 |
| Early stage larvae | 0 | 0 |
| Unidentified sp. 2 | 0 | 0 |
| Unidentified sp. 4 | 10 | 0 |
| Unidentified sp. 5 | 0 | 0 |
| Unidentified sp. 6 | 0 | 0 |
| Total #fish/station | 1347 | 949 |
| Total fish without sardines | 231 | 105 |

| | Traps | |
|---|---------|------|
| | Shallow | Deep |
| Acanthuridae | | |
| <i>Acanthurus bahianus</i> | 0 | 6 |
| <i>Acanthurus chirurgus</i> | 15 | 38 |
| <i>Acanthurus coeruleus</i> | 0 | 2 |
| Apogonidae | | |
| <i>Apogon maculatus</i> | 1 | 0 |
| <i>Apogon planifrons</i> | 1 | 0 |
| Apogonid sp. | 0 | 0 |
| Apogonidae sp. 1 | 0 | 0 |
| Apogonidae sp. 2 | 0 | 0 |
| Apogonidae sp. 3 | 0 | 0 |
| Apogonidae sp. 4 | 0 | 0 |
| Apogonidae sp. 5 | 0 | 0 |
| <i>Astrapogon puncticulatus</i> | 0 | 0 |
| <i>Astrapogon stellatus</i> | 1 | 0 |
| <i>Phaeoptyx conklini</i> | 0 | 0 |
| <i>Phaeoptyx pigmentarius</i> | 1 | 1 |
| Blenniidae | | |
| Blenniidae sp.2 | 2 | 0 |
| <i>Ophioblenius atlanticus</i> | 6 | 1 |
| <i>Malocotenus macropus</i> | 5 | 0 |
| Bothidae | | |
| <i>Bothus lunatus</i> | 0 | 0 |
| <i>Bothus ocellatus</i> | 0 | 0 |
| Bregmacerotidae | | |
| <i>Bregmaceros atlanticus</i> | 8 | 15 |
| Carangidae | | |
| <i>Chloroscombrus chrysurus</i> | 5 | 0 |
| <i>Decapterus</i> sp. | 0 | 0 |
| <i>Selene vomer</i> | 0 | 0 |
| Chaetodontidae | | |
| <i>Chaetodon capistratus</i> | 1 | 3 |
| <i>Chaetodon striatus</i> | 0 | 0 |
| Chaenopsidae | | |
| <i>Hemiblemmaria simulus</i> | 0 | 0 |
| Congridae | | |
| <i>Heteroconger halis</i> | 0 | 0 |
| Dactylopteridae | | |
| <i>Dactylopterus volitans</i> | 0 | 0 |
| Diodontidae | | |
| <i>Diodon hystrix</i> | 0 | 0 |
| Eels | | |
| Eel var sp. | 0 | 0 |
| Elopidae | | |
| <i>Megalops atlanticus</i> | 31 | 5 |
| Gerreidae | | |
| <i>Eucinostomus melanopterus</i> | 581 | 1 |
| Gobiesocidae | | |
| <i>Acyrtops beryllina</i> | 0 | 0 |
| Gobiidae | | |
| <i>Coryphopterus dicrus</i> | 0 | 1 |
| <i>Coryphopterus glaucofraenum</i> | 0 | 0 |
| <i>Coryphopterus personatus</i> | 0 | 0 |
| <i>Gnatholepis thompsoni</i> | 2 | 3 |
| <i>Gobiosoma saucrum</i> | 0 | 0 |
| Gobiidae sp. 1 | 0 | 0 |
| Gobiidae sp. 2 | 1 | 2 |
| Gobiidae sp. 3 | 0 | 12 |
| Gobiidae sp. 4 | 0 | 0 |
| Gobiidae sp. 5 | 0 | 0 |
| Gobiidae sp. 6 | 0 | 0 |
| Gobiidae sp. 7 (poss. <i>Nes longus</i>) | 0 | 0 |
| Haemulidae | | |
| <i>Haemulon aurolineatum</i> | 31 | 0 |
| Hemiramphidae | | |
| <i>Hyporhamphus unifasciatus</i> | 0 | 0 |
| Holocentridae | | |
| <i>Holocentrus vexillarius</i> | 0 | 1 |

| | Traps | |
|---|---------|------|
| | Shallow | Deep |
| Labridae | 10 | 2 |
| <i>Halichoeres bivattatus</i> | 0 | 1 |
| <i>Halichoeres garnoti</i> | 0 | 0 |
| <i>Halichoeres maculipinna</i> | 0 | 0 |
| <i>Halichoeres poeyi</i> | 0 | 0 |
| Labridae sp. 2 | 0 | 0 |
| Labridae sp. 3 (poss. <i>H. pictus</i>) | 0 | 0 |
| Labridae sp. 4 | 0 | 0 |
| Labridae sp. 5 | 0 | 0 |
| <i>Thalassoma bifasciatum</i> | 12 | 0 |
| Labrisomidae | | |
| <i>Labrisomus nuchipinnis</i> | 0 | 0 |
| <i>Malacotenus macropus</i> | 0 | 0 |
| <i>Malacotenus triangulatus</i> | 0 | 0 |
| Lutjanidae | | |
| <i>Lutjanus apodus</i> | 3 | 0 |
| <i>Lutjanus buccanella</i> | 0 | 0 |
| <i>Lutjanus chrysurus</i> | 2 | 0 |
| <i>Lutjanus mahogani</i> | 24 | 0 |
| Monacanthidae | | |
| <i>Monacanthus setifer</i> | 6 | 0 |
| Mullidae | | |
| <i>Pseudupeneus maculatus</i> | 1 | 2 |
| Polynemidae | | |
| <i>Polydactylus virginicus</i> | 0 | 1 |
| Pomacanthidae | | |
| <i>Pomacanthus arcuatus</i> | 0 | 0 |
| Pomacentridae | | |
| <i>Abudefduf saxatilis</i> | 0 | 0 |
| <i>Stegastes dorsopunicans</i> | 57 | 9 |
| <i>Stegastes leucostictus</i> | 4 | 0 |
| <i>Stegastes planifrons</i> | 61 | 1 |
| <i>Stegastes partitus</i> | 36 | 6 |
| <i>Stegastes variabilis</i> | 1 | 1 |
| <i>Microspathodon chrysurus</i> | 0 | 0 |
| Priacanthidae | | |
| <i>Priacanthus cruentatus</i> | 0 | 1 |
| Scombridae | | |
| <i>Scomberomorus regalis</i> | 1 | 0 |
| Scorpaenidae | | |
| Serranidae | | |
| <i>Epinephelus striatus</i> | 0 | 0 |
| Serranidae sp. 1 | 0 | 0 |
| Sphyraenidae | | |
| <i>Sphyraena barracuda</i> | 0 | 0 |
| Sygnathidae | | |
| <i>Cosmocomps elucens (M. crinitus?)</i> | 0 | 0 |
| Synodontidae | | |
| <i>Synodus intermedius</i> | 47 | 16 |
| Tetraodontidae | | |
| <i>Sphoeroides spengleri</i> | 0 | 0 |
| Trichiuridae | | |
| <i>Trichiurus lepturus</i> | 0 | 11 |
| Clupeoids | | |
| <i>Anchoa lyolepis</i> (Engraulidae) | 708 | 195 |
| <i>Jenkinsia lamprotaenia</i> (Clupeidae) | 1293 | 99 |
| <i>Atherinomorus stipes</i> (Atherinidae) | 5 | 0 |
| Unidentified | | |
| Damaged | 6 | 0 |
| Early stage larvae | 2 | 0 |
| Unidentified sp. 2 | 0 | 0 |
| Unidentified sp. 4 | 1 | 0 |
| Unidentified sp. 5 | 0 | 0 |
| Unidentified sp. 6 | 0 | 0 |
| Total #fish/station | 2982 | 436 |
| Total fish without sardines | 976 | 142 |

| | Traps | |
|---|---------|------|
| | Shallow | Deep |
| Acanthuridae | | |
| <i>Acanthurus bahianus</i> | 0 | 0 |
| <i>Acanthurus chirurgus</i> | 0 | 0 |
| <i>Acanthurus coeruleus</i> | 1 | 0 |
| Apogonidae | | |
| <i>Apogon maculatus</i> | 1 | 20 |
| <i>Apogon planifrons</i> | 0 | 0 |
| Apogonid sp. | 11 | 20 |
| Apogonidae sp. 1 | 0 | 7 |
| Apogonidae sp. 2 | 3 | 48 |
| Apogonidae sp. 3 | 0 | 5 |
| Apogonidae sp. 4 | 0 | 0 |
| Apogonidae sp. 5 | 0 | 0 |
| <i>Astrapogon puncticulatus</i> | 7 | 0 |
| <i>Astrapogon stellatus</i> | 52 | 3 |
| <i>Phaeoptyx conklini</i> | 0 | 80 |
| <i>Phaeoptyx pigmentarius</i> | 5 | 11 |
| Blenniidae | | |
| Blenniidae sp.2 | 0 | 0 |
| <i>Ophioblennius atlanticus</i> | 6 | 0 |
| <i>Malacoctenus macropus</i> | 0 | 6 |
| Bothidae | | |
| <i>Bothus lunatus</i> | 0 | 0 |
| <i>Bothus ocellatus</i> | 0 | 1 |
| Bregmacerotidae | | |
| <i>Bregmaceros atlanticus</i> | 1 | 0 |
| Carangidae | | |
| <i>Chloroscombus chrysurus</i> | 2 | 0 |
| <i>Decapterus</i> sp. | 2 | 0 |
| <i>Selene vomer</i> | 0 | 0 |
| Chaetodontidae | | |
| <i>Chaetodon capistratus</i> | 0 | 0 |
| <i>Chaetodon striatus</i> | 0 | 0 |
| Chaenopsidae | | |
| <i>Hemimblemaria simulus</i> | 0 | 0 |
| Congridae | | |
| <i>Heteroconger halis</i> | 0 | 2 |
| Dactylopteridae | | |
| <i>Dactylopterus volitans</i> | 0 | 0 |
| Diodontidae | | |
| <i>Diodon hystrix</i> | 0 | 0 |
| Eels | | |
| Eel var sp. | 0 | 0 |
| Elopidae | | |
| <i>Megalops atlanticus</i> | 1 | 1 |
| Gerreidae | | |
| <i>Eucinostomus melanopterus</i> | 20 | 1 |
| Gobiesocidae | | |
| <i>Acyrtops beryllina</i> | 1 | 0 |
| Gobiidae | | |
| <i>Coryphopterus dicrus</i> | 0 | 63 |
| <i>Coryphopterus glaucofraenum</i> | 0 | 11 |
| <i>Coryphopterus personatus</i> | 0 | 0 |
| <i>Gnatholepis thompsoni</i> | 0 | 1 |
| <i>Gobiosoma saucrum</i> | 0 | 5 |
| Gobiidae sp. 1 | 0 | 51 |
| Gobiidae sp. 2 | 0 | 154 |
| Gobiidae sp. 3 | 0 | 17 |
| Gobiidae sp. 4 | 0 | 10 |
| Gobiidae sp. 5 | 0 | 3 |
| Gobiidae sp. 6 | 0 | 2 |
| Gobiidae sp. 7 (poss. <i>Nes longus</i>) | | |
| Haemulidae | | |
| <i>Haemulon aurolineatum</i> | 3 | 0 |
| Hemiramphidae | | |
| <i>Hyporhamphus unifasciatus</i> | 0 | 0 |
| Holocentridae | | |
| <i>Holocentrus vexillarius</i> | 0 | 0 |

| | Traps | |
|---|---------|------|
| | Shallow | Deep |
| Labridae | 21 | 60 |
| <i>Halichoeres bivattatus</i> | 1 | 2 |
| <i>Halichoeres garnoti</i> | 0 | 0 |
| <i>Halichoeres maculipinna</i> | 0 | 0 |
| <i>Halichoeres poeyi</i> | 0 | 0 |
| Labridae sp. 2 | 13 | 120 |
| Labridae sp. 3 (poss. <i>H. pictus</i>) | 0 | 8 |
| Labridae sp. 4 | 0 | 1 |
| Labridae sp. 5 | 0 | 0 |
| <i>Thalassoma bifasciatum</i> | 39 | 1 |
| Labrisomidae | | |
| <i>Labrisomus nuchipinnis</i> | 1 | 1 |
| <i>Malacoctenus macropus</i> | 0 | 0 |
| <i>Malacoctenus triangulatus</i> | 1 | 0 |
| Lutjanidae | | |
| <i>Lutjanus apodus</i> | 7 | 0 |
| <i>Lutjanus buccanella</i> | 10 | 0 |
| <i>Lutjanus chrysurus</i> | 1 | 0 |
| <i>Lutjanus mahogani</i> | 26 | 0 |
| Monacanthidae | | |
| <i>Monacanthus setifer</i> | 0 | 0 |
| Mullidae | | |
| <i>Pseudupeneus maculatus</i> | 0 | 0 |
| Polynemidae | | |
| <i>Polydactylus virginicus</i> | 1 | 0 |
| Pomacanthidae | | |
| <i>Pomacanthus arcuatus</i> | 0 | 0 |
| Pomacentridae | | |
| <i>Abudefduf saxatilis</i> | 1 | 0 |
| <i>Stegastes dorsopunicans</i> | 29 | 0 |
| <i>Stegastes leucostictus</i> | 2 | 0 |
| <i>Stegastes planifrons</i> | 7 | 0 |
| <i>Stegastes partitus</i> | 19 | 0 |
| <i>Stegastes variabilis</i> | 1 | 0 |
| <i>Microspathodon chrysurus</i> | 1 | 0 |
| Priacanthidae | | |
| <i>Priacanthus cruentatus</i> | 1 | 0 |
| Scombridae | | |
| <i>Scomberomorus regalis</i> | 1 | 0 |
| Scorpaenidae | | |
| Serranidae | | |
| <i>Epinephelus striatus</i> | 1 | 0 |
| Serranidae sp. 1 | 0 | 0 |
| Sphyraenidae | | |
| <i>Sphyraena barracuda</i> | 0 | 0 |
| Sygnathidae | | |
| <i>Cosmocampus elucens (M.crinatus?)</i> | 0 | 0 |
| Synodontidae | | |
| <i>Synodus intermedius</i> | 36 | 169 |
| Tetraodontidae | | |
| <i>Sphoeroides spengleri</i> | 0 | 0 |
| Trichiuridae | | |
| <i>Trichiurus lepturus</i> | 0 | 0 |
| | 0 | 0 |
| Clupeioids | | |
| <i>Anchoa lyolepis (Engraulidae)</i> | 976 | 72 |
| <i>Jenkinsia lamprotaenia (Clupeidae)</i> | 3063 | 4907 |
| <i>Atherinomorus stipes (Atherinidae)</i> | 14 | 0 |
| Unidentified | | |
| Damaged | 0 | 44 |
| Early stage larvae | 0 | 50 |
| Unidentified sp. 2 | 10 | 15 |
| Unidentified sp. 4 | 1 | 2 |
| Unidentified sp. 5 | 0 | 1 |
| Unidentified sp. 6 | 0 | 0 |
| Total #fish/station | 4400 | 5975 |
| Total fish without sardines | 347 | 999 |

Appendix I

Fish larvae caught during the second cycle in Sail Rock

| | Traps | |
|---|---------|------|
| | Shallow | Deep |
| Acanthuridae | | |
| <i>Acanthurus bahianus</i> | 0 | 0 |
| <i>Acanthurus chirurgus</i> | 1 | 1 |
| <i>Acanthurus coeruleus</i> | 0 | 0 |
| Apogonidae | | |
| <i>Apogon maculatus</i> | 3 | 2 |
| <i>Apogon planifrons</i> | 7 | 1 |
| Apogonid sp. | 0 | 32 |
| Apogonidae sp. 1 | 0 | 27 |
| Apogonidae sp. 2 | 0 | 103 |
| Apogonidae sp. 3 | 0 | 2 |
| Apogonidae sp. 4 | 0 | 3 |
| Apogonidae sp. 5 | 0 | 0 |
| <i>Astrapogon puncticulatus</i> | 0 | 0 |
| <i>Astrapogon stellatus</i> | 96 | 2 |
| <i>Phaeoptyx conklini</i> | 0 | 63 |
| <i>Phaeoptyx pigmentarius</i> | 5 | 103 |
| Blenniidae | | |
| Blenniidae sp.2 | 0 | 0 |
| <i>Ophioblennius atlanticus</i> | 3 | 0 |
| <i>Malacoctenus macropus</i> | 0 | 0 |
| Bothidae | | |
| <i>Bothus lunatus</i> | 0 | 0 |
| <i>Bothus ocellatus</i> | 0 | 1 |
| Bregmacerotidae | | |
| <i>Bregmaceros atlanticus</i> | 0 | 12 |
| Carangidae | | |
| <i>Chloroscombrus chrysurus</i> | 2 | 0 |
| <i>Decapterus</i> sp. | 0 | 0 |
| <i>Selene vomer</i> | 0 | 0 |
| Chaetodontidae | | |
| <i>Chaetodon capistratus</i> | 0 | 0 |
| <i>Chaetodon striatus</i> | 0 | 0 |
| Chaenopsidae | | |
| <i>Hemimblemaria simulus</i> | 0 | 5 |
| Congridae | | |
| <i>Heteroconger halis</i> | 0 | 2 |
| Dactylopteridae | | |
| <i>Dactylopterus volitans</i> | | |
| Diodontidae | | |
| <i>Diodon hystrix</i> | 0 | 0 |
| Eels | | |
| Eel var sp. | 0 | 0 |
| Elopidae | | |
| <i>Megalops atlanticus</i> | 0 | 0 |
| Gerreidae | | |
| <i>Eucinostomus melanopterus</i> | 59 | 0 |
| Gobiesocidae | | |
| <i>Acyrtops beryllina</i> | 0 | 0 |
| Gobiidae | | |
| <i>Coryphopterus dicrus</i> | 0 | 3 |
| <i>Coryphopterus glaucofraenum</i> | 0 | 0 |
| <i>Coryphopterus personatus</i> | 1 | 0 |
| <i>Gnatholepis thompsoni</i> | 0 | 5 |
| <i>Gobiosoma saucrum</i> | 0 | 2 |
| Gobiidae sp. 1 | 0 | 7 |
| Gobiidae sp. 2 | 0 | 89 |
| Gobiidae sp. 3 | 0 | 16 |
| Gobiidae sp. 4 | 0 | 13 |
| Gobiidae sp. 5 | 0 | 1 |
| Gobiidae sp. 6 | 0 | 1 |
| Gobiidae sp. 7 (poss. <i>Nes longus</i>) | 1 | 8 |
| Haemulidae | | |
| <i>Haemulon aurolineatum</i> | 2 | 2 |
| Hemiramphidae | | |
| <i>Hyporhamphus unifasciatus</i> | 0 | 0 |
| Holocentridae | | |
| <i>Holocentrus vexillarius</i> | 0 | 0 |

| | Traps | |
|--|---------|------|
| | Shallow | Deep |
| Labridae | 0 | 6 |
| <i>Halichoeres bivattatus</i> | 0 | 3 |
| <i>Halichoeres garnoti</i> | 0 | 1 |
| <i>Halichoeres maculipinna</i> | 0 | 0 |
| <i>Halichoeres poeyi</i> | 1 | 0 |
| Labridae sp. 2 | 0 | 125 |
| Labridae sp. 3 (poss. <i>H. pictus</i>) | 0 | 36 |
| Labridae sp. 4 | 0 | 3 |
| Labridae sp. 5 | 0 | 2 |
| <i>Thalassoma bifasciatum</i> | 27 | 5 |
| Labrisomidae | | |
| <i>Labrisomus nuchipinnis</i> | 0 | 0 |
| <i>Malacoctenus macropus</i> | 0 | 0 |
| <i>Malacoctenus triangulatus</i> | 1 | 0 |
| Lutjanidae | | |
| <i>Lutjanus apodus</i> | 9 | 0 |
| <i>Lutjanus buccanella</i> | 0 | 0 |
| <i>Lutjanus chrysurus</i> | 0 | 0 |
| <i>Lutjanus mahogani</i> | 35 | 5 |
| Monacanthidae | | |
| <i>Monacanthus setifer</i> | 0 | 0 |
| Mullidae | | |
| <i>Pseudupeneus maculatus</i> | 1 | 0 |
| Polynemidae | | |
| <i>Polydactylus virginicus</i> | 0 | 0 |
| Pomacanthidae | | |
| <i>Pomacanthus arcuatus</i> | 1 | 0 |
| Pomacentridae | | |
| <i>Abudefduf saxatilis</i> | 0 | 0 |
| <i>Stegastes dorsopunicans</i> | 12 | 0 |
| <i>Stegastes leucostictus</i> | 1 | 0 |
| <i>Stegastes planifrons</i> | 15 | 0 |
| <i>Stegastes partitus</i> | 27 | 0 |
| <i>Stegastes variabilis</i> | 0 | 0 |
| <i>Microspathodon chrysurus</i> | 1 | 0 |
| Priacanthidae | | |
| <i>Priacanthus cruentatus</i> | 0 | 0 |
| Scombridae | | |
| <i>Scomberomorus regalis</i> | 0 | 0 |
| Scorpaenidae | | |
| Serranidae | | |
| <i>Epinephelus striatus</i> | 0 | 0 |
| Serranidae sp. 1 | 0 | 1 |
| Sphyraenidae | | |
| <i>Sphyraena barracuda</i> | 0 | 0 |
| Sygnathidae | | |
| <i>Cosmocampus elucens</i> (<i>M. crinitus</i> ?) | 0 | 0 |
| Synodontidae | | |
| <i>Synodus intermedius</i> | 17 | 108 |
| Tetraodontidae | | |
| <i>Sphaeroides spengleri</i> | 0 | 0 |
| Trichiuridae | | |
| <i>Trichiurus lepturus</i> | 0 | 0 |
| | 0 | 0 |
| Clupeoids | | |
| <i>Anchoa lyolepis</i> (Engraulidae) | 217 | 10 |
| <i>Jenkinsia lamprotaenia</i> (Clupeidae) | 624 | 688 |
| <i>Atherinomorus stipes</i> (Atherinidae) | 20 | 1 |
| Unidentified | | |
| Damaged | 2 | 24 |
| Early stage larvae | 0 | 38 |
| Unidentified sp. 2 | 3 | 54 |
| Unidentified sp. 4 | 0 | 0 |
| Unidentified sp. 5 | 0 | 1 |
| Unidentified sp. 6 | 0 | 4 |
| Total #fish/station | 1194 | 1621 |
| Total fish without sardines | 333 | 922 |

| | Traps | |
|---|---------|------|
| | Shallow | Deep |
| Acanthuridae | | |
| <i>Acanthurus bahianus</i> | 4 | 4 |
| <i>Acanthurus chirurgus</i> | 7 | 6 |
| <i>Acanthurus coeruleus</i> | 0 | 0 |
| Apogonidae | | |
| <i>Apogon maculatus</i> | 7 | 8 |
| <i>Apogon planifrons</i> | 4 | 0 |
| Apogonid sp. | 3 | 0 |
| Apogonidae sp. 1 | 0 | 50 |
| Apogonidae sp. 2 | 6 | 55 |
| Apogonidae sp. 3 | 0 | 1 |
| Apogonidae sp. 4 | 0 | 0 |
| Apogonidae sp. 5 | 0 | 26 |
| <i>Astrapogon puncticulatus</i> | 0 | 3 |
| <i>Astrapogon stellatus</i> | 38 | 5 |
| <i>Phaeoptyx conklini</i> | 4 | 49 |
| <i>Phaeoptyx pigmentarius</i> | 6 | 22 |
| Blenniidae | | |
| Blenniidae sp.2 | 0 | 0 |
| <i>Ophioblennius atlanticus</i> | 10 | 0 |
| <i>Malocotenus macropus</i> | 0 | 4 |
| Bothidae | | |
| <i>Bothus lunatus</i> | 0 | 0 |
| <i>Bothus ocellatus</i> | 0 | 0 |
| Bregmacerotidae | | |
| <i>Bregmaceros atlanticus</i> | 7 | 41 |
| Carangidae | | |
| <i>Chloroscombrus chrysurus</i> | 3 | 0 |
| <i>Decapterus</i> sp. | 0 | 0 |
| <i>Selene vomer</i> | 0 | 1 |
| Chaetodontidae | | |
| <i>Chaetodonton capistratus</i> | 0 | 3 |
| <i>Chaetodonton striatus</i> | 0 | 0 |
| Chaenopsidae | | |
| <i>Hemimblemaria simulus</i> | 1 | 10 |
| Congridae | | |
| <i>Heteroconger halis</i> | 0 | 1 |
| Dactylopteridae | | |
| <i>Dactylopterus volitans</i> | 0 | 0 |
| Diodontidae | | |
| <i>Diodon hystrix</i> | 0 | 0 |
| Eels | | |
| Eel var sp. | 0 | 0 |
| Elopidae | | |
| <i>Megalops atlanticus</i> | 0 | 4 |
| Gerreidae | | |
| <i>Eucinostomus melanopterus</i> | 163 | 3 |
| Gobiesocidae | | |
| <i>Acyrtops beryllina</i> | 0 | 0 |
| Gobiidae | | |
| <i>Coryphopterus dicrus</i> | 0 | 23 |
| <i>Coryphopterus glaucofraenum</i> | 0 | 1 |
| <i>Coryphopterus personatus</i> | 0 | 1 |
| <i>Gnatholepis thompsoni</i> | 0 | 25 |
| <i>Gobiosoma saucrum</i> | 0 | 3 |
| Gobiidae sp. 1 | 0 | 24 |
| Gobiidae sp. 2 | 0 | 237 |
| Gobiidae sp. 3 | 0 | 6 |
| Gobiidae sp. 4 | 0 | 61 |
| Gobiidae sp. 5 | 0 | 4 |
| Gobiidae sp. 6 | 0 | 4 |
| Gobiidae sp. 7 (poss. <i>Nes longus</i>) | 0 | 21 |
| Haemulidae | | |
| <i>Haemulon aurolineatum</i> | 4 | 0 |
| Hemiramphidae | | |
| <i>Hyporhamphus unifasciatus</i> | 0 | 0 |
| Holocentridae | | |
| <i>Holocentrus vexillarius</i> | 0 | 0 |

| | Traps | |
|--|---------|------|
| | Shallow | Deep |
| Labridae | 1 | 3 |
| <i>Halichoeres bivattatus</i> | 1 | 1 |
| <i>Halichoeres garnoti</i> | 2 | 0 |
| <i>Halichoeres maculipinna</i> | 0 | 1 |
| <i>Halichoeres poeyi</i> | 0 | 0 |
| Labridae sp. 2 | 0 | 71 |
| Labridae sp. 3 (poss. <i>H. pictus</i>) | 1 | 37 |
| Labridae sp. 4 | 0 | 2 |
| Labridae sp. 5 | 0 | 0 |
| <i>Thalassoma bifasciatum</i> | 100 | 10 |
| Labrisomidae | | |
| <i>Labrisomus nuchipinnis</i> | 0 | 0 |
| <i>Malacotenus macropus</i> | 0 | 0 |
| <i>Malacotenus triangulatus</i> | 1 | 0 |
| Lutjanidae | | |
| <i>Lutjanus apodus</i> | 14 | 0 |
| <i>Lutjanus buccanella</i> | 0 | 0 |
| <i>Lutjanus chrysurus</i> | 13 | 0 |
| <i>Lutjanus mahogani</i> | 55 | 3 |
| Monacanthidae | | |
| <i>Monacanthus setifer</i> | 5 | 1 |
| Mullidae | | |
| <i>Pseudupeneus maculatus</i> | 1 | 0 |
| Polynemidae | | |
| <i>Polydactylus virginicus</i> | 1 | 1 |
| Pomacanthidae | | |
| <i>Pomacanthus arcuatus</i> | 0 | 0 |
| Pomacentridae | | |
| <i>Abudefduf saxatilis</i> | 1 | 0 |
| <i>Stegastes dorsopunicans</i> | 123 | 0 |
| <i>Stegastes leucostictus</i> | 4 | 0 |
| <i>Stegastes planifrons</i> | 32 | 0 |
| <i>Stegastes partitus</i> | 78 | 0 |
| <i>Stegastes variabilis</i> | 0 | 0 |
| <i>Microspathodon chrysurus</i> | 4 | 0 |
| Priacanthidae | | |
| <i>Priacanthus cruentatus</i> | 0 | 0 |
| Scombridae | | |
| <i>Scomberomorus regalis</i> | 5 | 0 |
| Scorpaenidae | | |
| Serranidae | | |
| <i>Epinephelus striatus</i> | 0 | 0 |
| Serranidae sp. 1 | 0 | 1 |
| Sphyraenidae | | |
| <i>Sphyraena barracuda</i> | 1 | 0 |
| Sygnathidae | | |
| <i>Cosmocampus elucens (M. crinitus?)</i> | 0 | 0 |
| Synodontidae | | |
| <i>Synodus intermedius</i> | 69 | 49 |
| Tetraodontidae | | |
| <i>Sphoeroides spengleri</i> | 0 | 0 |
| Trichiuridae | | |
| <i>Trichiurus lepturus</i> | 0 | 0 |
| Clupeoids | | |
| <i>Anchoa lyolepis (Engraulidae)</i> | 132 | 109 |
| <i>Jenkinsia lamprotaenia (Clupeidae)</i> | 1371 | 1183 |
| <i>Atherinomorlus stipes (Atherinidae)</i> | 27 | 0 |
| Unidentified | 6 | 3 |
| Damaged | 0 | 10 |
| Early stage larvae | 0 | 21 |
| Unidentified sp. 2 | 2 | 30 |
| Unidentified sp. 4 | 1 | 0 |
| Unidentified sp. 5 | 0 | 0 |
| Unidentified sp. 6 | 1 | 2 |
| Total #fish/station | 2319 | 2244 |
| Total fish without sardines | 789 | 952 |