

# Rapid changes in fish utilization of mangrove habitat in Western Madagascar

Judith S. Weis · Peddrick Weis · James MacDonald · Louis Pearson

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**Abstract** Fish use of a mangrove habitat was studied in a small mangrove forest on the West coast of Madagascar. A sand bar near the inlet retains water in parts of the channel (pools) at low tide. Fishes in four of these pools were examined daily at all phases of the tidal cycle for 3 weeks using underwater visual census. During week 1, fishes were diverse and abundant in all pools: the dominant species were cardinalfish (related to *Apogon lateralis*); monos, *Monodactylus argenteus*; black spotted snappers, *Lutjanus ehrenbergi*; double bar bream, *Acanthopagrus bifasciatus*; emperors, *Lethrinus lentjan* and *L. sp.*, surgeon fish, *Acanthurus nigricauda*; red-lined sweetlips, *Plectorhinchus plagiodesmis*; and butterflyfish, *Chaetodon kleini*. Some species were more abundant in shaded pools; others in more open pools. During week 2 a dramatic difference was noted:

the only fishes found were schools of cardinalfish and one moray eel. This week had neap tides, with high tides in the morning and low tides in the afternoon. As the week progressed and during week 3 (spring tides), fishes slowly repopulated the habitat and diversity increased. Monos, absent in week 2, now had increasing numbers of small individuals. While large emperors were scarce, small individuals appeared. The larger butterflyfish and surgeonfish seen in week 1 were replaced by small ones during week 3. Species that had been rare in week 1 were more abundant, including pipefish and small barracudas. While species richness increased during week 3, the community was strikingly different from that seen 2 weeks earlier. Only Pool 1, closest to the entrance, recovered its original species richness. Abundance was much lower than in week 1. Our snapshot study apparently captured a time when older juveniles left the mangrove forest and smaller fishes recruited into it. Utilization of this habitat will likely vary throughout the year depending on the reproductive cycle of the different species whose juveniles utilize it. Longer studies are needed to learn about cycles in fish use of the mangroves.

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J. S. Weis (✉) · J. MacDonald  
Department of Biological Sciences, Rutgers University,  
Newark, NJ 07102, USA  
e-mail: jweis@andromeda.rutgers.edu

J. MacDonald  
e-mail: macdja@gmail.com

P. Weis  
Department of Radiology, University of Medicine  
and Dentistry of NJ, Newark, NJ 07103, USA  
e-mail: weis@umdnj.edu

L. Pearson  
Blue Ventures, 52 Avenue Rd., London N6 5DR,  
England, UK  
e-mail: louispearson@hotmail.com

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## Introduction

In tropical regions, mangrove habitats are utilized by many fish as feeding and/or nursery areas. Many of

these species are found as adults on coral reefs. Studies in many regions have documented which species utilize mangroves, what habitat aspects attract them, and at what life history stages. In general, mangroves are considered to be useful to juveniles for protection from predators and to a lesser extent for feeding. The physical structure provided by prop roots, pneumatophores, fallen branches and trunks provides protection, while epibionts on the prop roots provide additional attraction (Laegdsgaard and Johnson 2001). Detritus, microflora and microfauna, as well as aquatic macrophytes and their epiflora and fauna, can provide food (Blaber 2000; Verweij et al. 2006). Frequently turbid waters may reduce visual predator effectiveness, and their shallowness excludes larger predators (Ellis and Bell 2004; Shulman 1985).

The nursery role of mangrove habitats has been demonstrated by studies in the Caribbean showing that their presence influences fish assemblages on nearby coral reefs (Nagelkerken et al. 2002; Halpern 2004; Mumby et al. 2004). In the Indo-Pacific region there is less consensus regarding linkages between mangrove and coral reef habitats. Some studies have found less importance of mangroves as nursery habitat (Kimani et al. 1996; Huxham et al. 2004), but other studies have found a strong linkage between mangrove habitats and reef fishes, especially for particular species (Dorenbosch et al. 2005, 2006).

There has been only one published study on fish use of Madagascar mangrove forests (Laroche et al. 1997), so we undertook to examine the fish community in a mangrove forest in southwestern Madagascar over 3 weeks in January 2008, in order to see which species were utilizing this small habitat, and compare results with other studies in the Indian Ocean.

## Materials and methods

### Site description

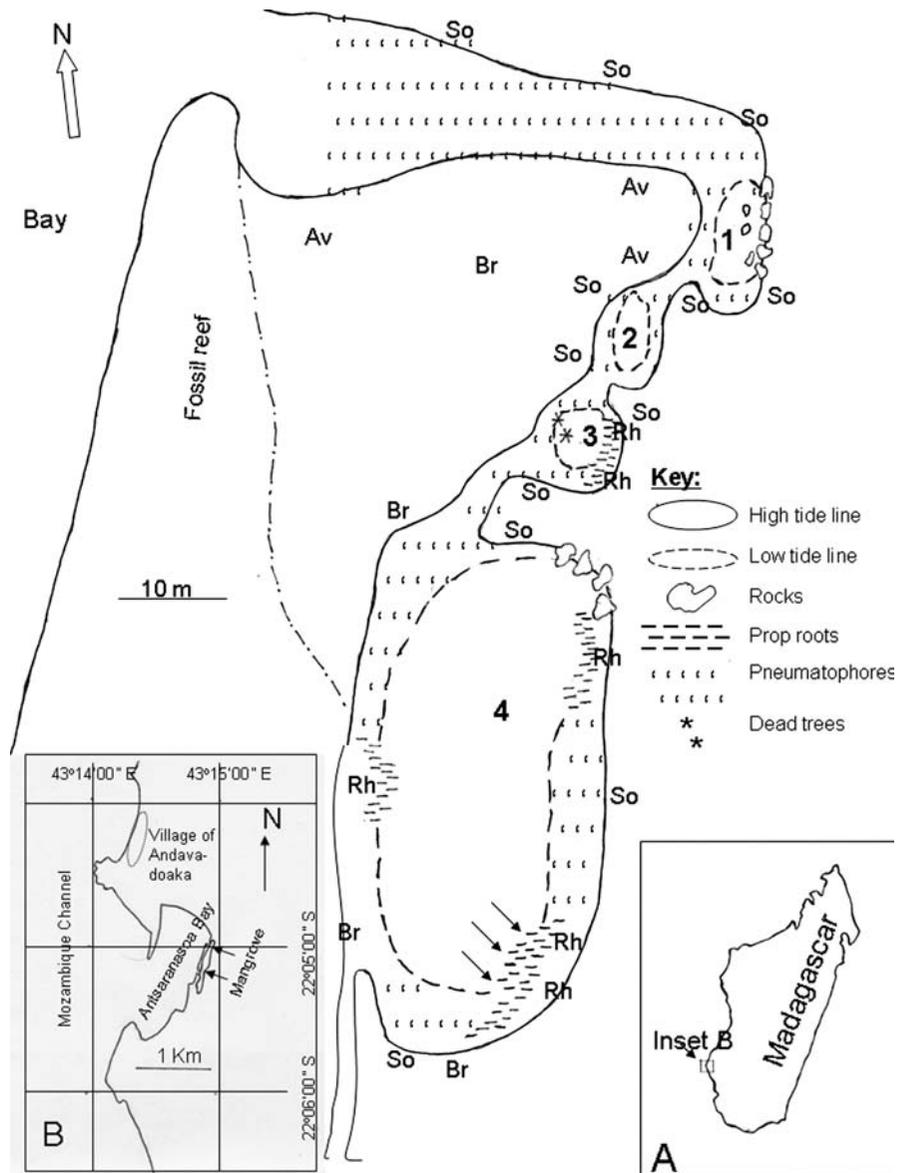
The Antsaranasoa mangrove forest comprises a small area (1,200 m × 300 m) just south-east of the village of Andavadoaka in southwestern Madagascar. The system has fossil coral outcroppings in many places, including on much of the seaward side. The forest contains five species of mangroves: *Avicennia marina* (Forsk.), *Bruguiera gymnorrhiza* (L.), *Ceriops tagal*

(Perr.), *Rhizophora mucronata* (Lam.), and *Sonneratia alba* (J. Smith). There are inlets for sea water to enter the system during flood tides. There is little or no freshwater input. It is on a bay with extensive seagrass beds and is ~2 km from offshore reefs.

This study focused on the northernmost inlet where there is a sand bar that delays the inflow of water at flood tide and allows standing water to remain in parts of the channel at low tide. This is in contrast to some other Indo-Pacific mangrove forests where no water is left at low tide and fish must move elsewhere (Laroche et al. 1997). At low tide here, there are deeper pools, and the fishes found in these pools were studied during all phases of the tidal cycle, over 3 weeks, using underwater visual census (UVC) by snorkeling.

Pool 1 (Fig. 1) is 41 m from the entrance, at S 22°04'57.5" × E 43°14'57.0" as determined by on-site GPS readings (eTrex, Garmin Co., Taiwan) and comprises about 35 m<sup>2</sup>. It has fossil coral rock on one side and pneumatophores of *Avicennia* and *Sonneratia* on the other sides and is 47 cm deep at spring low tide. Pool 2 begins 8 m southwest of Pool 1, comprises about 20 m<sup>2</sup> in area and is 61 cm deep at spring low tide. It is more shaded than Pool 1 and is surrounded primarily by *Sonneratia* as well as some *Avicennia*, which cause most of the pool to be shaded for many hours. Pool 3 begins 7 m south of Pool 2, comprises about 20 m<sup>2</sup> in area, and is more open, with direct sunlight during most of the day, with *Sonneratia* and *Rhizophora* on the sides and a large dead tree trunk lying in it. It is 38 cm deep at low tide. Pool 4 is a long channel that starts 11 m past Pool 3. The channel is about 40 m long (centered at S 22°05'01.0" × E 43°14'55.5") and is lined primarily by *Rhizophora* on one side and *Rhizophora* plus some *Bruguiera* and sandy and rocky areas on the other side. During spring low tide, most of it is too shallow for snorkeling, so only a small area (~15 m<sup>2</sup>) near the south end of Pool 4, among the prop roots of *Rhizophora* trees, was selected for study; this area was 47 cm deep at spring low tide (Fig. 1). Since it was among the prop roots, it was generally shaded for most of the day. Beyond Pool 4 is another long, shallow channel, which breaks up into small rivulets that drain more interior parts of the mangrove forest; this was not examined for fish. Although *C. tagal* is present in the forest, it is not close to any of the four pools studied.

**Fig. 1** Map of Madagascar region, and the mangrove pools, showing locations of different mangrove tree species. Arrows at south end of Pool 4 indicate specific study area. Av, *Avicennia marina*; So, *Sonneratia alba*; Rh, *Rhizophora mucronata*; Br, *Bruguiera gymnorhiza*



Fishes in all pools were counted daily by underwater visual census (UVC) by at least two observers, 30 min each per pool each day. Their sizes were estimated to the nearest cm using a ruler attached to a slate. The periphery and interior of all pools were examined carefully at least twice on each visit by each observer, as were all roots and rocks and all potential hiding places for small fishes. Fish were examined during all phases of the tidal cycle except for a 2-h period during flood and ebb tides when the water was moving too quickly for observations. Most observations were around the low tide, while some were around high

tide. The salinity inside and outside the site was measured by refractometer in all areas, both before and after rare rainstorms, and was consistently 36. Species richness, abundance and density per pool were compared by ANOVA, followed by Bonferroni comparisons, using the Statistix<sup>®</sup> program. Biomass of fish in each pool was calculated using published length/weight relationships for each dominant species of fish (<http://www.fishbase.org>). Species assemblages (mean values/pool) were compared using cluster analysis with the Euclidian distance and group-average linkage method, performed using PC-Ord v. 4.0.

## Results

During the first week (5 days, January 8–12), fish were diverse and abundant in all pools. The dominant species that were seen regularly were large schools of cardinalfish, related to *Apogon lateralis* (Valenciennes) (2–6 cm, perhaps a subspecies due to small but consistent differences in appearance), followed by, in order of decreasing abundance, monos, *Monodactylus argenteus* (L.) (3–7 cm TL); black spot snappers, *Lutjanus ehrenbergii* (Peters) 7–13 cm; double bar bream, *Acanthopagrus bifasciatus* (Forsskål) (9–13 cm); pinkear emperors, *Lethrinus lentjan* (Lacepède) and *L. sp.* (6–10 cm); black streak surgeon fish, *Acanthurus nigricauda* (Duncker & Mohr) (3–5 cm); red-lined or barred sweetlips, *Plectorhinchus plagiodesmis* (Fowler) (8–12 cm); Klein's butterfly fish, *Chaetodon kleinii* (Bloch) (3–5 cm); and the brushtail tang, *Zebbrasoma scopas* (Cuvier) (3–5 cm). Table 1 lists all the species observed that could be identified.

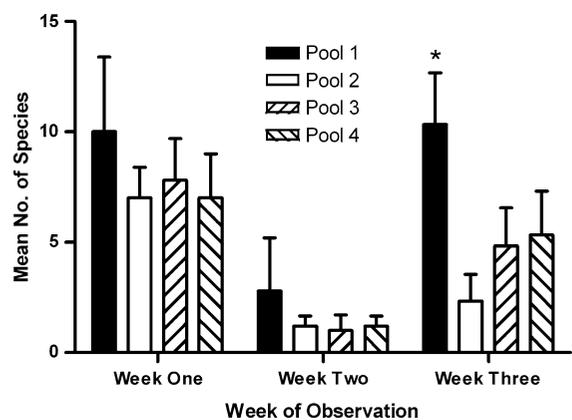
**Table 1** Species list: fish found in Antsaranasoa mangroves that could be identified

<i>Abedefduf natalensis</i> (Hensley & Randall), natal sergeant
<i>A. sparoides</i> (Quoy and Gaimard), false eye sergeant
<i>Acanthopagrus bifasciatus</i> (Forsskål), double bar bream*
<i>Acanthurus nigricauda</i> (Duncker & Mohr), black streak surgeon*
<i>Apogon sp.</i> (related to <i>lateralis</i> ) (Valenciennes), cardinalfish*
<i>Chaetodon kleinii</i> (Bloch), Klein's butterfly fish*
<i>Cheilodipterus quinquelineatus</i> (Cuvier), 5-lined cardinalfish
<i>Choeroichthys sculptus</i> (Günther), sculptured pipefish*
<i>Epinephalus ongus</i> (Bloch), speckled fin grouper
<i>Gerres acinaces</i> (Bleeker), black tip mojarra
<i>Gymnothorax permistus</i> (Smith) black-blotched moray*
<i>Lethrinus lentjan</i> (Lacepède), pink ear emperor*
<i>Lethrinus sp.</i> emperor
<i>Lutjanus ehrenbergii</i> (Peters) black spotted snapper*
<i>Monodactylus argenteus</i> (L.), mono*
<i>Plectorhinchus plagiodesmis</i> (Fowler), red lined sweetlips*
<i>Siderea picta</i> (Ahl), peppered moray*
<i>Sphyaena jello</i> (Cuvier), pickhandle barracuda*
<i>Terapon jarbua</i> (Forsskål), crescent banded grunter
<i>Trachyrampus bicoarctatus</i> (Bleeker), double-ended pipefish*
<i>Valamugil engeli</i> (Bleeker), fringe lipped mullet*
<i>Zebbrasoma scopas</i> (Cuvier), brushtail tang*

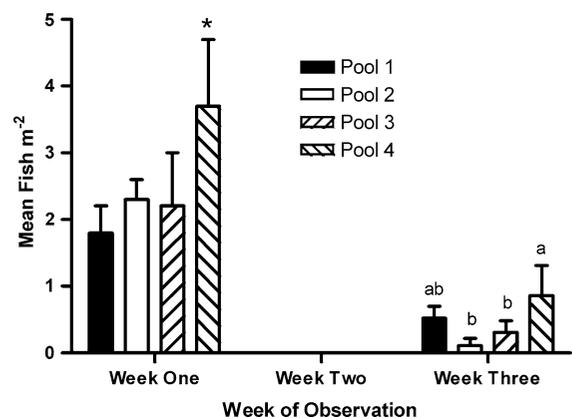
Those with asterisks are those found frequently

Species richness in Pool 1 was somewhat higher than in the other pools (Fig. 2), but the differences among pools were not statistically significant ( $F = 2.47$ ,  $P \leq 0.107$ ). The Shannon–Wiener  $H'$  was 2.01 for Pool 1, 1.30 for Pool 2, 1.79 for Pool 3, and 1.41 for Pool 4.

Overall abundance (number of fish per pool) averaged 45–65 fish. When considered in terms of fish density (since the pools differed in size) density averaged 1.8 fish  $m^{-2}$  in Pool 1, 2.3 in Pool 2, 2.2 in Pool 3 and 3.7 in Pool 4, a significant difference ( $F = 6.14$ ,  $P \leq 0.009$  (Fig. 3). Bonferroni indicates that density in Pool 4 was greater than in the other three pools. The cardinalfish were by far the most



**Fig. 2** Species richness of fishes in the four pools during the 3 weeks of the study. Asterisk indicates significant difference (Bonferroni) among pools within that week of the study



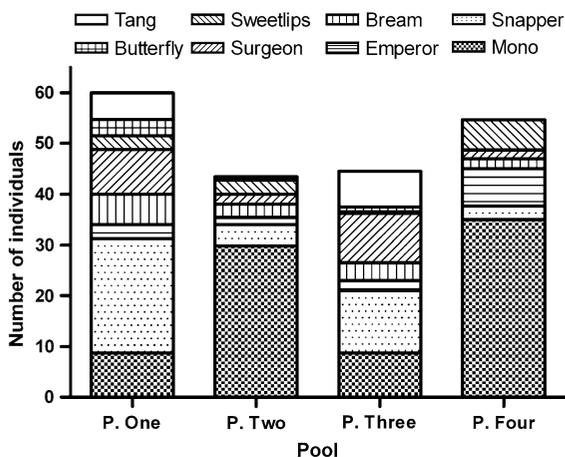
**Fig. 3** Density of fishes in the four pools during the 3 weeks of the study. Asterisk in week 1 indicates significantly different density than in the other pools. Letters above bars in week 3 indicates significantly different pools (Bonferroni)

abundant, forming large, constantly moving schools, probably in excess of 100 fish per pool; these could not be counted accurately and therefore were left out of the abundance estimates.

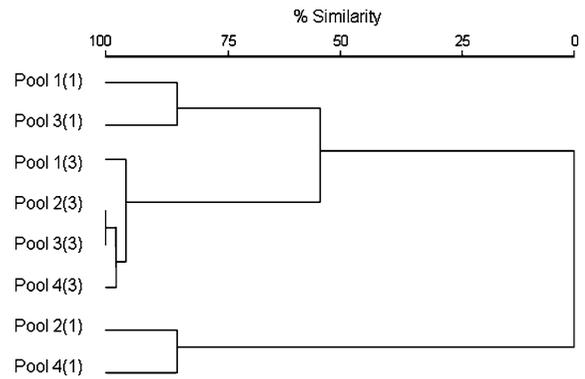
Biomass calculations (excluding cardinals) revealed that there was approximately 40 g fish m<sup>-2</sup> in Pools 1–3, and over 60 g fish m<sup>-2</sup> in Pool 4. As with the density comparisons, these differences were statistically significant ( $F = 5.87$ ,  $P \leq 0.01$ ) and Bonferroni indicated that the biomass in Pool 4 was significantly higher than in the other pools.

With the exception of the cardinalfish, the community assemblages were not uniform throughout the four pools. The monos averaged about 30 individuals in Pools 2 and 4, but only about 9 in Pools 1 and 3. Black spot snappers were much more abundant in Pools 1 and 3 (averaging 22.5 and 12.3 individuals, respectively) than in Pools 2 and 4, where they averaged only 4.2 and 2.7 individuals, respectively. The species composition in the different pools is shown in Fig. 4. Overall assemblages were most similar between the two shaded pools (Pools 2 and 4) and between the two more open pools (Pools 1 and 3) during week 1 (Fig. 5).

For several species (monos, snappers, bream, emperors), when all individuals in the four pools were combined, a decline in overall numbers was observed toward the end of week 1. Monos declined from over 90 to 70, snappers from about 40 to 20, bream from about 20 to 10, and emperors from about 20 to 3. The decline may have been an indication of things to come.



**Fig. 4** Species composition patterns of the dominant fish species in the four pools during week 1



**Fig. 5** Cluster analysis of species assemblage by pool. Pools 1 and 3 were open, more sunny, Pools 2 and 4 were shady with less heterogeneous habitat. Numbers in parenthesis indicate the week of the study

During the second week (5 days) a dramatic shift was noted. After one day of no observations, UVC was resumed daily and the only fish found were the schools of cardinalfish, and a moray eel in Pool 1. This was a week of neap tides, with high tides in the morning and low tides in the afternoon. On following days the same pattern of a depleted fish community persisted. The pools were examined daily both during the high tide mornings and low tide afternoons, and water temperature in the afternoon low tide was very hot, estimated at  $\sim 40^{\circ}\text{C}$ , though not measured. Only cardinalfish, prawns, palaemonid shrimp and crabs remained in the system. Some of the “missing” species (bream, snappers, and monos) were observed on the outside of the fossil coral near the entrance to the mangrove forest.

As the week progressed, there was an indication that fish were slowly repopulating the site and diversity was increasing, which continued during the third week (6 days, spring tides again), when abundance and diversity continued to increase. Additional surgeonfish, monos, emperors, gobies and mullets appeared. However, the surgeonfish were about 2 cm, smaller than those seen previously (and too small to visually identify to species), and the monos were about 2 cm. However, the larger fish that comprised much of the biomass in week 1—black spot snapper, double bar bream, and red lined sweetlips—were not present. Monos, common in week 1 and absent during week 2, were represented by increasing numbers (from 2 up to 14 by week’s end) of very small individuals (2 cm). Similarly, while larger emperors, butterflyfish, and surgeonfish

were scarce, small individuals (2–3 cm) appeared. In addition, two species of pipefish (double-ended pipefish, *Trachyrampus bicoarctatus* (Bleeker) and sculptured pipefish, *Choeroichthys sculptus* (Günther) were noted frequently. Species that had been rare in week 1 became more abundant, including small (5–6 cm) pick-handle barracudas (*Sphyraena jello*) (Cuvier).

While species richness increased during week 3 (Fig. 2), only in Pool 1 did it become equivalent to that in week 1, and the fish community throughout the system was strikingly different from that seen earlier. Comparing the pools with each other in week 3, species richness showed significant differences ( $F = 19.58$ ,  $P = 0.0001$ ). Bonferroni showed that Pool 1 was significantly more diverse than the other pools, which were similar to each other. In all pools, species richness was significantly higher in week 1; in Pools 1, 3 and 4 species richness was significantly higher in week 3 than week 2, indicating some recovery of diversity (Pool 1:  $F = 14.64$ ,  $P < 0.0005$ ; Pool 2:  $F = 38.60$ ,  $P = 0.00001$ ; Pool 3:  $F = 22.57$ ,  $P < 0.0001$ ; Pool 4:  $F = 14.98$ ,  $P \leq 0.0007$ , Fig. 2). Because of the reduction in numbers of the formerly dominant species, the Shannon–Wiener  $H'$  was a bit higher than in week 1, with  $H'$  of 2.37 for Pool 1, 1.87 for Pool 2, 2.01 for Pool 3 and 1.70 for Pool 4.

Overall density (not counting the cardinalfish), was much lower than in week 1 (Fig. 3). Density was also significantly different among the pools during week 3 and highest in Pool 4 due to the smaller study area. ANOVA revealed significant differences ( $F = 8.94$ ,  $P < 0.006$ ), and Bonferroni indicated density in Pool 4 (a)  $>$  1 (ab)  $>$  3, 2, (b). Pool 2 had the least recovery. In all pools, fish density in week 1 was significantly higher than in weeks 2 and 3, despite the increase in numbers during week 3 (Pool 1,  $F = 21.68$ ,  $P < 0.0001$ ; Pool 2,  $F = 526.82$ ,  $P < 0.000001$ ; Pool 3,  $F = 54.64$ ,  $P = 0.00001$ ; for Pool 4,  $F = 18.33$ ,  $P < 0.0003$ , Fig. 3).

Species assemblages in all the pools during week 3 were very closely related to each other, far more so than to themselves in week 1 (Fig. 5).

## Discussion

The community in all the pools in week 1 had similar species richness and abundance. The study area of

Pool 4 (the smallest area) had the greatest density and the greatest biomass. However, unlike the other pools, which were self-contained and isolated at low tide, the study area in Pool 4 was connected to the rest of the much larger pool, and fishes could enter and leave the study area, so it is not completely comparable to the other pools.

The pools also differed in the species of mangrove present. Vance et al. (1996) and Rönnbäck et al. (1999) indicated that the fish species composition varied with the species of mangrove. Vance et al. (1996) found more fish at a *Rhizophora* site of an Australian mangrove forest than *Ceriops*-dominated areas. The mangrove forest here had *Ceriops*, but this species did not border on any of the pools. The mangrove species did differ in that Pools 1 and 2 were dominated by *Sonneratia* and Pools 3 and 4 dominated by *Rhizophora*. The sampling area in Pool 4 was by *Rhizophora* prop roots but fish could come from elsewhere in the pool into these roots. Rönnbäck et al. (1999) found that fish in a Philippine mangrove forest preferred pneumatophores of *Avicennia* to prop roots of *Rhizophora*, and that the highest abundance was in the most inland habitat, in contrast to the findings of Vance et al. (1996). Rönnbäck et al. (1999) suggested that pneumatophores provide fish with more food compared to the less dense prop root environment. In our study, the species of mangrove seemed less important since the fish communities in Pools 1 and 3 were more similar to each other despite different dominant mangrove species. Shade, which would reduce predation risk, would appear to be an important factor in affecting our community composition. Verweij et al. (2006) found shade a much less important factor attracting fishes to artificial mangroves than structure and food, although in an overall less shady environment than in our naturally shaded pools.

Pool 1 contained several species not seen elsewhere, perhaps due to its proximity to the forest entrance and greater amount of pebbly habitat. The proximity to the entrance from the bay did not appear to affect Pool 2. Pools 2 and 4 were more shaded than Pools 1 and 3 and had more monos, while Pools 1 and 3 had more snappers and surgeons. The open vs. shaded aspects of the pools appeared to be more relevant than rocks vs. roots/pneumatophores, as supported by the clustering of assemblages based on open or shaded pool characteristics.

Cardinalfish were by far the most numerous throughout the system and persisted throughout the observation period. They appear to be a new species related to *A. lateralis* (T. Fraser, pers. commun.) since they lack a stripe and small black spot. They are likely to remain in mangrove forests their whole life. All the other fish species are considered juveniles, as they were smaller than one-third of the maximum length (Nagelkerken and van der Velde 2002). Juveniles of pinkear emperor and monos are considered brackish water species, spending early life stages in mangrove habitats (Froese and Pauly 2000). Their presence suggests that the habitat is selected for its structural or shade aspects, since the salinity was as high as open water. A number of studies indicate that reef fish larvae actively select their settlement habitat (Fisher and Bellwood 2003; Lecchini et al. 2005).

It was a great surprise to note the absence of fish during week 2. Some “missing” species were observed near the entrance to the mangrove forest, which may represent the first step on their way to a reef. Large scale community changes can be driven by environmental factors such as salinity and turbidity changes during the rainy season (De Morais and de Morais 1994; Cyrus and Blaber 1987), but no such changes occurred here. Also, responses to environmental changes tend to be species-specific (Tzeng and Wang 1992; Barletta-Bergan et al. 2002), but multiple species left our system simultaneously. Tzeng and Wang (1992) noted that the juveniles of four dominant species in their mangrove environment had separate peaks of immigration and seasonal utilization of the habitat.

In a prior study in another Madagascar mangrove fish community, Laroche et al. (1997) sampled several times a month throughout a year with gillnets and found different dominant species, although *S. bifasciatus* was common. They captured a different suite of fishes in the Saradrano mangrove forest south of Tulear, dominated by Gerreidae, Teraponidae, Carangidae and Sparidae; these differences may result from differing sampling methods (netting vs. visual census). Their community showed clear seasonal patterns, though some species were abundant all year. They found no effects of changes in salinity or turbidity but suggested that tidal and lunar effects were more important, as may have been the case in the present study. They noted rapid species turnover as indicated by the disappearance of up to eight

species and the appearance of up to nine species from one month to the next. Since in the present study, sampling was more frequent (daily), it was possible to note the disappearance or appearance of species over a shorter time frame. Among the changes they noted were large decreases in *M. argenteus* between January and February, similar to our findings. Since they used gillnets with the smallest stretch mesh of 50 mm, they would not have been able to capture the smaller individuals found by UVC.

It may be that the fishes seen in week 1 left the mangrove forest because they had reached the developmental stage at which this ontogenetic habitat shift normally occurs, although smaller individuals of those species also left. They may have all been from the same cohort and had reached the same phase of development though some were larger than others. It was surprising that many different species left simultaneously; they may have all responded to some unknown environmental cue. The departure was 6–7 days after the new moon spring tides. Laroche et al. (1997) also noted effects of tides and moon phases on the assemblage, with *A. bifasciatus* most abundant during the new moon, corresponding to our observations.

During week 3, recruitment of new monos, emperors, butterflyfish and surgeonfish was seen. High salinity mangrove habitats have their highest primary production during the hot and dry season (Yanez-Arancibia et al. 1988), which can cause seasonal variation in fish recruitment. The main recruitment period for mangrove fishes is the late dry to mid-wet season (January in Madagascar), although this particular area remains quite dry in the wet season. No recruitment of double bar bream, black spot snappers, or sweetlips was observed, however. In the southern Arabian Gulf, double bar bream and black spot snappers were in peak spawning condition in February and April–July, respectively (Grandcourt et al. 2003, 2006); if the same applies in Madagascar, new recruits would not be expected to arrive for a few more months.

In Zanzibar, which is relatively close geographically, the mangrove fish community was dominated by mojarras (*Gerres* spp.) (a few here), emperors (a dominant), and monos (another dominant). Fish density and biomass decreased from January to February (Lugendo et al. 2007), similar to our observations. Species richness increased slightly from

January to February and then decreased during the rainy season; this was attributed to altered salinity. Pinkear emperor recruits decreased from January to February (the opposite of what we found) while density of larger individuals did not change, also different from current observations. In Zanzibar, barracuda (*Sphyraena barracuda*) (Walbaum) recruits decreased from January to February, while the pickhandle barracuda, *S. jello*, increased in the present study. Lugendo et al. (2007) noted an increase in small monos and a decrease in larger individuals from January to February, which was observed here. Four of the seven species they studied had recruits in the mangroves in January and February, which corresponds to this study in which monos, surgeons, butterflyfish and emperor recruits appeared in late January.

The reasons for the dramatic changes in the fish community are not completely understood, although the data indicate that our “snapshot” look corresponded to a time when larger juveniles of most species left the mangroves for other habitats, and when smaller fish were subsequently recruiting into the system. It was adaptive that the recruitment of the small juveniles occurred after the departure of the larger ones, in that potential predators were no longer present. Coral reef fishes that use mangrove habitats spawn at the reef and migrate in as post-larvae (Little et al. 1988), and many of the species, including sweetlips, emperors, Klein’s butterfly, and surgeonfish, have seasonal spawning aggregations at the reefs (Claydon 2004). Timing of spawning has been shown to match spatial and temporal proximity of recruits with food items (Dickey-Collas et al. 1996), so it also might also be timed to match reduction of potential predators. In addition, fish larvae can actively select their settlement habitat (Fisher and Bellwood 2003; Lecchini et al. 2005). Sweatman (1988) found that damselfish, *Dascyllus* sp., recruited preferentially to coral heads with more adult conspecifics, using olfactory cues. If they can use olfaction to enhance settlement in some areas, it is possible that olfactory cues from potential predators could deter settlement. Alternatively, if larvae recruited into the system earlier when the larger juveniles were present, they may not have survived due to predation, as black spot snappers are piscivores (Blaber et al. 1990) and red-ear emperors are carnivores (Salini et al. 1994). Settlement preferences do not completely match the

juvenile habitat; not all recruited to the same pool types (e.g., open vs. shaded) as their older counterparts. This may reflect a drawn out settlement process where recruits sort out into their preferred habitat over a few weeks, or may indicate that different life stages utilize habitats differently. Pool 2, while supporting a diverse assemblage during week 1, subsequently supported very few recruits.

Additional sporadic observations were made in the pools at 3, 6, 8, and 11 weeks after our final observations. These showed gradual increases in diversity in all pools, although Pool 2 continued to have lowest diversity and abundance. There was no trend of spring tides having greater fish abundance than weeks of neap tides. Monos continued to increase, both new recruits and larger individuals. Snappers re-appeared and increased in abundance, primarily in Pool 1 until the 8th and 11th weeks when they were most abundant in Pool 4. Mangrove jacks became more abundant throughout the system, but primarily in Pool 4. Mojarras became regulars throughout the system. Mulletts appeared abundantly in Pool 4 also. However, there were no double bar bream, and the sweetlips was an occasional visitor rather than a dominant resident of the system as before.

Although this study occurred over a short time and in a small area, it was clear that this small mangrove forest is actively used by a diverse juvenile fish assemblage (It is interesting to note that if the study had commenced one week later, we would have concluded that fish do not utilize this habitat. Erroneous conclusions like that could lead to inappropriate management of mangroves and other wetlands). As the only mangrove forest along this part of the coastline, it has high diversity, density, and biomass compared with some other much larger mangrove areas (Giarrizzo and Krumme 2008). During this brief survey we encountered about 12% of the number of species noted in a longer survey of fishes on the nearby reefs (Gillibrand et al. 2007). The persistence of water at low tide instead of emptying of the system (and need to move), which can cause low abundance of fish in other Indo-Pacific mangroves (Dorenbosch et al. 2004; Jelbart et al. 2007; Weis and Weis 2005) may make this an attractive habitat. Fish utilization of this habitat will vary throughout the year depending on reproductive cycles of the different species. Community dynamics

will depend on recruitment and residence times of the different species. Longer studies are needed throughout the year to learn about cycles in use—recruitment, residence times, and departure—by the different fish species and life stages in mangroves over annual periods. Such studies could determine if this rapid response of fishes simultaneously leaving the mangrove habitat is typical in this area.

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