TIDES AND SEASCAPE CONFIGURATION: DETERMINANTS OF REEF FISH INTERTIDAL MIGRATION IN THE TROPICAL EASTERN PACIFIC (COLOMBIA)

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Abstract

On coasts with high tidal ranges fishes regularly enter and leave the intertidal zone searching for food and/or refuge. The linkage established between sub tidal and intertidal habitats via these movements may differentially regulate important life history processes largely unknown in fish populations. To examine the responses of shallow-water reef fish assemblages to water level changes in a macro tidal area of the tropical eastern Pacific, a series of daytime underwater visual surveys of fishes over strip transects were carried out at different tidal stages (flood, high, ebb and low tide) in the Utría National Park, Colombia (November 2007- March 2008).

At four different sites, a total of 36 permanent 25 x 2 m transects at mid intertidal, low intertidal and sub tidal areas were established (three transects per zone). To preliminary assess the potential influence that wave exposure and proximity to mangroves and coral reef areas of the park had on these assemblages, two sites were located close to mangrove/coral reefs and in sheltered areas, and the two others were situated in exposed areas distant from the mangrove/coral reef area. Overall, 106 species were found during the study period with a predominance (relative abundance) of Labridae (*Thalassoma lucasanum*) and Pomacentridae (*Stegates acapulcoensis, Chromis atrilobata*) species.

More than 70% of these species used the adjacent rocky intertidal areas. Benthic opportunistic reef species comprised ca. 85% of the intertidal migrants, whereas the remaining 15% corresponded to reef ubiquitous and pelagic species. Parametric ANOVA, Non-parametric Kruskal Wallis and multivariate ANOSIM tests showed that (1) sub tidal fish species richness, densities and structure did not change significantly between spring/neap tides and over the tidal and lunar cycles, (2) intertidal fish densities, species richness and structure differed significantly from those of sub tidal areas, and (3) the combination of wave exposure and proximity to mangrove/coral reefs did not show a clear effect on the structure of these assemblages. Tidal related movements in reef fishes are likely to operate differentially among species and within species among size classes. The generality and importance of the mechanism, however, remain to be tested. It is suggested that rocky intertidal habitats are alternative, non-essential habitats for most of the reef fishes in Utría. Seascape characteristics at both intertidal and sub tidal areas (e.g. slope, inundated area, wave exposure) may affect fish assemblage structures, but these effects are best observed within specific fish groups. Further reef fish monitoring in macro tidal areas should consider tides as a potential source of bias when specific fish populations and/or size classes are being surveyed.

Keywords: intertidal migration, rocky intertidal, reef fishes, tropical eastern Pacific, Utría

Introduction

The continuous movement of organisms during different stages of their life cycles can establish linkages between marine habitats. These movements, often referred to as habitat connectivity, are a critical aspect responsible for the maintenance of a large number of marine populations. In near-shore ecosystems, nektonic organisms may move selectively through several pathways connecting habitats. These movements are likely to be influenced by different local environmental processes, settings and by anthropogenic activities.

Two of these environmental variables are represented by the tidal cycle and the seascape configuration of habitats. Tidal variability, although a widely recognized force affecting coastal organisms is often neglected in connectivity studies, thus its effects and importance remain largely unknown. On the other hand, the local seascape configuration of habitats has proven to influence to a great extent why organisms select habitats and movement pathways. This selection is extremely related to differences in the potential risk to predation that certain habitat configurations may have for these organisms. The examination of these two important processes in tropical macro tidal areas may provide useful insights to understand what determines the connectivity between habitats at local scales, which in turn could contribute to the establishment of successful management strategies within Marine Protected Areas (MPAs).

In coastal waters of the tropical eastern Pacific (TEP), tidal amplitudes can reach ca. 4-5 m, and may exert a major influence on coastal animal's behaviour and distribution. Nevertheless, this dynamic is poorly understood for most of the coastal areas in the region. At the same time, the TEP shoreline, including the Colombian Pacific coast is dominated by rocky intertidal and sub tidal seascapes, representing nearly 30 % of the total shoreline in the Colombian case (636 km for the TEP). Mangroves, sandy bottoms and marginal coral reefs occur in between the predominant rocky areas, building a mosaic of interconnected living communities around them. These features place the TEP region as a suitable area to test the potential influence that tidal forces may have on reef fish assemblages and the role that seascape characteristics may play in shaping patterns of fish migration into rocky intertidal areas.

Considering that many fish use different habitats on short-term scales (e.g. daily home range movements) and that these movements may be as important as the long-term ones (e.g. ontogenetic habitat shifts), it is necessary to understand how these short-term movements operate. The inclusion of this kind of information into the management strategies of coastal resources, and the planning and designing of MPAs will help significantly to the success and fulfilment of their original objectives.

This study pretended to examine how reef fish movements into shallow rocky intertidal areas are determined by the tidal cycle and seascape characteristics. The project was carried out in a marine protected area (Parque Nacional Natural Utría) of the northern Colombian Pacific where macro-tidal regimes are present. The park has extensive rocky-shore lines and lies within two important areas for conservation, the Tumbes - Chocó - Magdalena biodiversity hotspot and the eastern tropical Pacific seascape corridor.

Methods

Study site. Utría is one of four National marine protected areas in the Colombian Pacific. Created in 1987, it is located in the northern part of the Pacific coast near the border with Panama between 5° 53` - 6° 11`N and 77° 9` - 77° 24` W and encompassing ca. 78000 ha (15000 ha marine). The park is embedded within the 250 km - long Baudó mountain range. The most conspicuous geological accident within the park is the Utría Sound, which is considered as an inverse fault formed in the late Cretaceous and composed mainly of basalts, gabbros and cherts from the same age. The Sound is four km long and 800 m wide at low tide with a south-north orientation and average depth of 30 m (Figure 1).

The terrestrial part of the park corresponds to a recognized bio diverse very humid tropical forest where elevations rarely exceed 1000 m. This vegetation frequently ends at steep cliffs that border the coastline. The marine area harbours relatively young mangrove areas (ca. 2600 yr B.P) in the inner part of Utría Sound, which were probably formed by an invasion of *Pelliciera rhizophorae* in former lowland rainforest due to a sea-level rise.

Despite this relatively recent invasion, Utría has seven of the 10 mangrove species present in the Colombian Pacific. The largest coral reef patch in the north of Colombia lies within the park with an extension of 10.5 ha. Located within the Sound in its east margin, the reef is characterized by a low species richness (only five species) and low live-coral cover (not exceeding 33%) presumably due to a mixture of adverse environmental conditions and past anthropogenic disturbances. Coral communities are dominated by *Pocillopora damicornis* (80%) and *Psammocora stellata* (16%) colonies. Other scattered coral colonies occur throughout sub tidal rocky substrates of the park. Apart from the mangrove areas and the impoverished coral reef patch in the inner part of the Sound, rocky intertidal and sub tidal shorelines constitute the predominant seascape of the park.

Although rains occur throughout the year, two climatic regimes can be observed in the area: a wet season from May to November and a dry season from December to April. Nevertheless, these conditions are highly variable and linked to the migration of the Inter-tropical Convergence Zone (ITCZ).

Annual precipitation can reach 7000 mm and relative humidity is 99% during the wet season. Air temperature ranges between 21 - 31° C with a mean of 25° C. Mean salinity in the Sound is 25, with higher variation towards inner zones due to run-off during the wet season. Water transparency, compared to other areas in the Colombian Pacific is high ranging from 4.5 to 14 m (secchi disc). The tide is semi-diurnal with tidal amplitudes exceeding 4 m at spring tides (macro tidal regime).

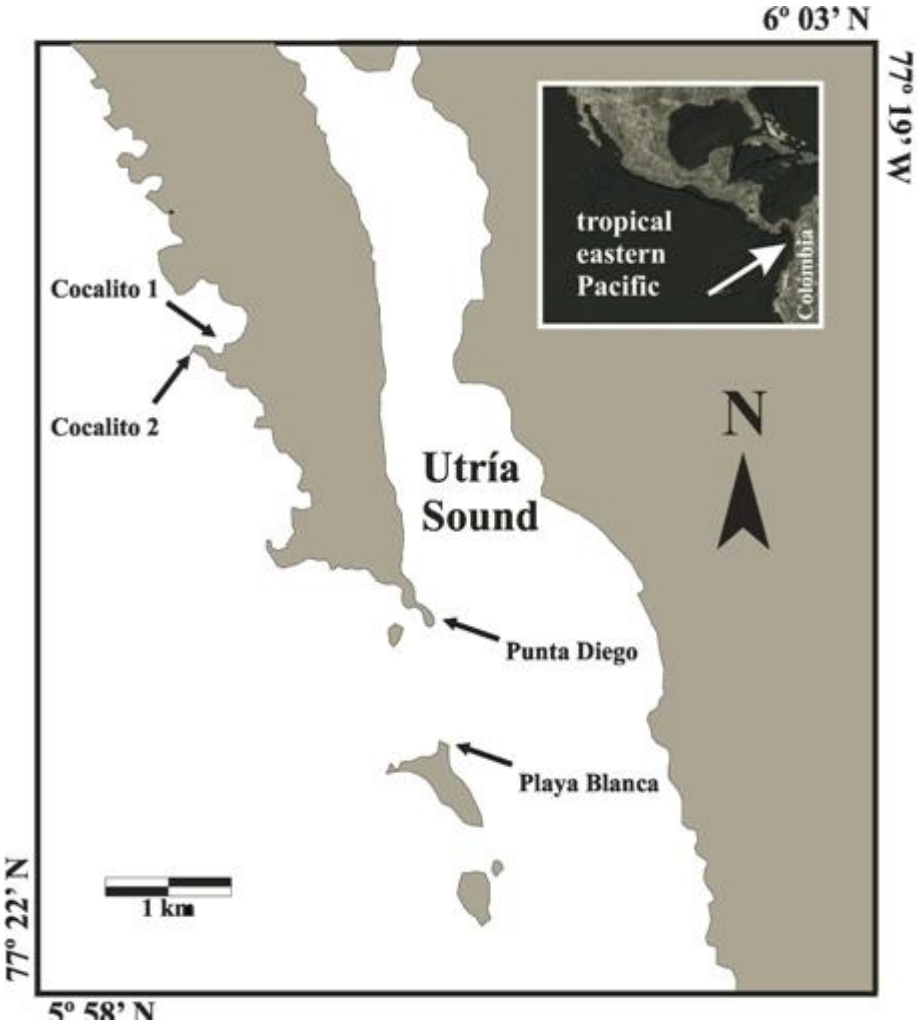

Figure 1. Geographic position of the Utría Sound within the tropical eastern Pacific. The four study sites are shown by arrows.

Sampling. A preliminary field trip to the Utría National Park took place during September 2007. From several sites visited in the inner and outer part of the Sound, four were selected. Two sites with moderate wave intensity were selected in the outer area of the sound. These sites (Cocalito 1 and Cocalito 2) were located more than 5 km away from the mangrove forests and the only coral reef patch in the area. The two other sites (Punta Diego and Playa Blanca) were located in sheltered areas of the inner part of the sound and less than 2 km away from the mangroves and the coral reef patch. In a subsequent field trip in November, nine permanent 25 x 2 m transects at each of the four selected sites were established and marked with painted stones (36 in total). The location of transects within each site followed a gradient from intertidal to sub tidal zones. Thus, transects were located at medium intertidal, low intertidal and sub tidal zones (three transect per zone). Finally, sub tidal transects were established in adjacent areas of the four sites in water depths less than three meters at low tide. Transects were selected trying to be as similar as possible in substrate cover. Within the same month and during two weeks two biologists trained in fish taxonomy visited the four sites and performed preliminary day-light underwater visual censuses (UVCs). After such calibration, sampling started from November to December 2007 and from the end of January to the beginning of March 2008 (Figure 2).

During this period, weekly UCVs were made at the four sites (one site per day) in the previously defined strip transects. Fish observations were made during most of the day

light tidal cycle covering low water, flood, ebb and high water periods. In visual observations fish species and number of individuals were recorded. Sampling time during the week was selected according to the days with the greatest or lowest tidal amplitude during spring or neap tide periods respectively (one or two days after each lunar phase). When water clarity was less than 3 m, censuses were interrupted.

Data were evaluated using a series of univariate and multivariate statistical tests (ANOVAs, Kruskal-Wallis, Mann Whitney, non Metric Multidimensional Scaling (nMDS), Analysis of Similarities (ANOSIM) and SIMPER).

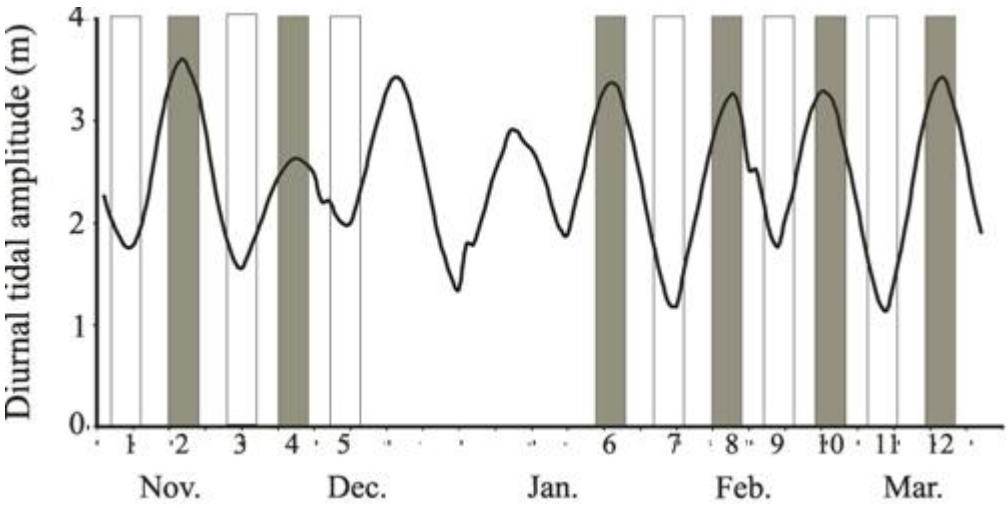

Figure 2. Sampling events with tidal amplitudes in neap (white bars) and spring tides (grey bars).

Results

A total of 66845 fish in 661 transect observations were counted at the four sites during the study period. Overall, 106 species belonging to 41 fish families were identified. Carangidae, Haemulidae, Labridae, Muraenidae, Pomacentridae and Serranidae were the most specious families with seven species each of them. *Thalassoma lucasanum* (Gill 1862), *Stegastes acapulcoensis* (Fowler 1944) and *Chromis atrilobata* Gill 1862, were the most abundant species combining all sites (relative abundance= 18.5, 15.3 and 13.8% respectively).

Mean sub tidal fish species richness over the tidal stages differed among sampling sites with the highest mean numbers observed in Playa Blanca and the lowest in Cocalito 2. These values ranged between 13 and 25 at Punta Diego, 17 and 28 in Playa Blanca, 15 and 20 in Cocalito 1, and seven and 22 in Cocalito 2. Furthermore, mean fish densities (Ind/50 m_2) were highly variable among tidal stages and sites with ranges between 83 and 235 in Punta Diego, 79 and 169 in Playa Blanca, 84 and 202 in Cocalito 1, and 38 and 199 in Cocalito 2 (Figure 3). The highest mean densities were observed in two of the Punta Diego transects, whereas mean densities in Cocalito 2 were extremely low in the first transect. No significant differences in mean species richness and mean densities in the sub tidal transects among tidal stages at any of the sites were observed. At the fish assemblage level, no significant differences were observed as revealed by the visual analysis of nMDS plots and the subsequent ANOSIM tests performed. The statistic Rvalue for the tidal stage factor was always near zero indicating no separation in the fish assemblage structure among low tide, ebb, high tide or flood.

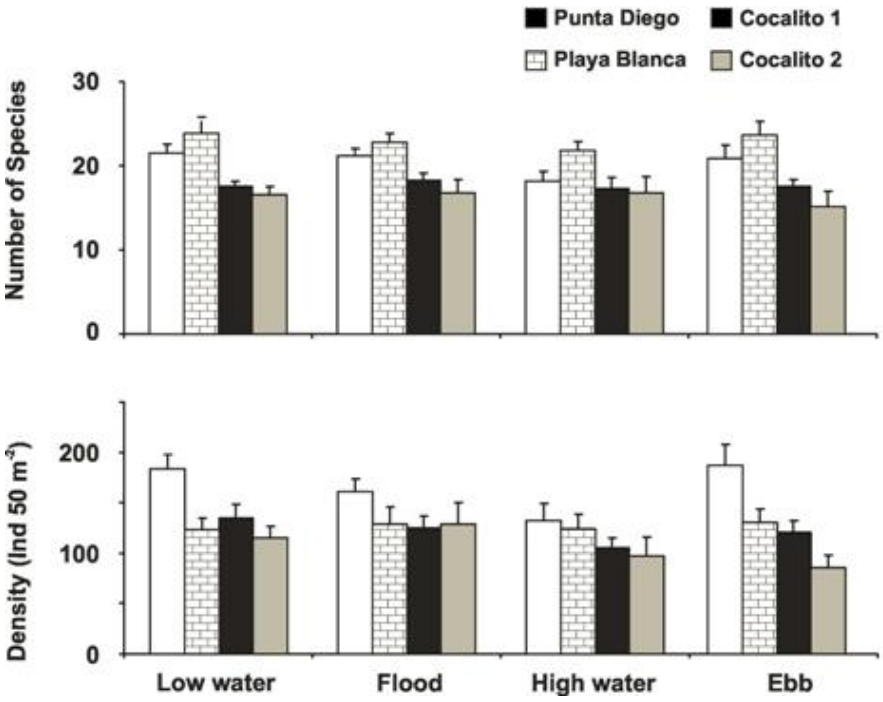

Figure 3. Mean number of species and fish density (+ SE) at the four study sites during tidal fluctuation (low water, flood, high water and ebb)

When sub tidal and intertidal assemblages were compared via nMDS and ANOSIM, a clear separation of groups was observed at three of the four study sites (Figure 4). The only site where a clear separation was not found was Playa Blanca. There the R-value from the ANOSIM test was below 0.5, indicating that that similarity between assemblages may not be significantly different.

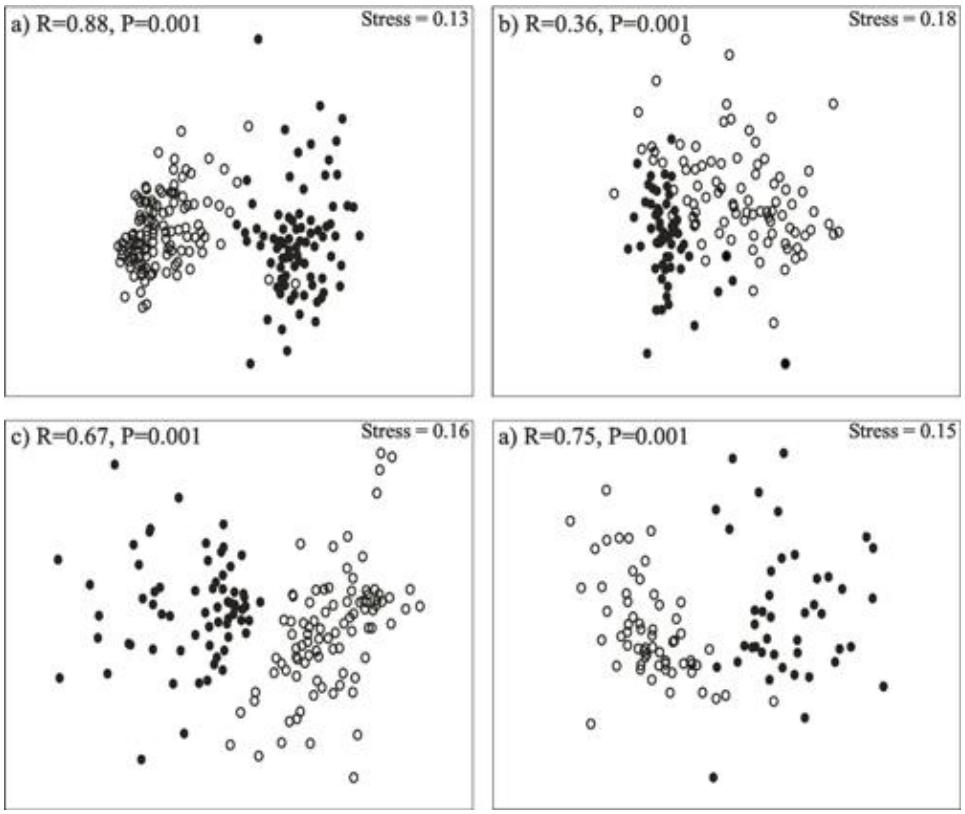

Figure 4. nMDS plot showing differences between intertidal (black dots) and sub tidal (white dots) fish assemblages at: a) Punta Diego, b) Playa Blanca, c) Cocalito 1 and d) Cocalito 2. ANOSIM R values indicate significant differences for all sites.

A clear separation in both intertidal and sub tidal assemblages at sites with different habitat configuration was not observed (Figure 5). This was revealed by the low global R-values obtained in the ANOSIM test. Sub tidal sheltered sites near mangrove/coral reefs (Punta Diego and Playa Blanca), however, were found in closer association (ANOSIM pair wise test, R=0.235, p=0.001). Similarly, the sub tidal wave exposed sites far from mangrove/coral reefs (both Cocalito sites) were more related (R=0.285, p=0.001). The greatest differences were observed between the Punta Diego-Cocalito 2, Punta Diego-Cocalito 2 and Playa Blanca-Cocalito 2 pair wise comparisons (R-values 0.519, 0.457 and 0.404 respectively; p=0.001).

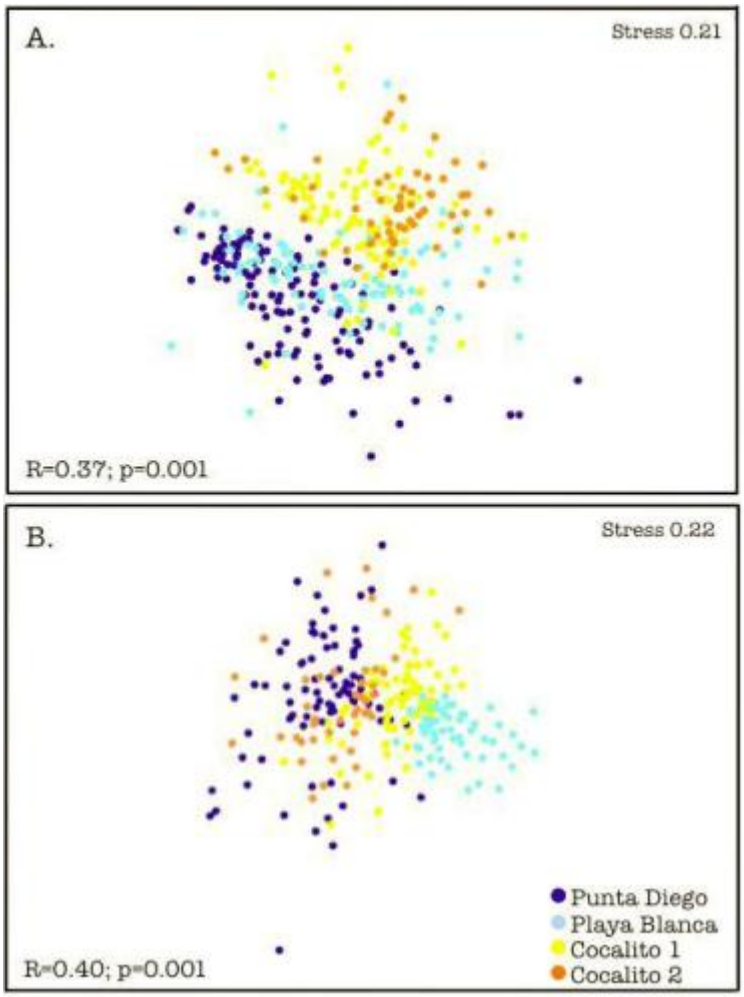

Figure 5. Non-metric multidimensional scaling (nMDS) representation of (A) sub tidal and (B) intertidal fish assemblages at the four study sites within Utría National Park. ANOSIM Global R values are given.

Conclusions

This study evaluated for the first time in the tropical eastern Pacific, the effect that tidal variation has on reef fish assemblages of the region. The results have shown that fish intertidal migrations into rocky shores of the Utría National park (Colombia, are a common feature in home-range movements of a relatively high number of coastal fishes. The principal components of this migrating fauna are benthic fishes coming from sub tidal reefs, though ubiquitous and pelagic fishes coming from more distant areas visit the intertidal zones regularly.

The observed lack of response to the tidal, spring/neap or lunar cycles in adjacent sub tidal fish assemblages may be indicative that migrations to the intertidal zone operate differentially among species and within size classes.

This was observed when intertidal and sub tidal fish assemblage's structures were compared and found substantially different. Hence, suggesting that migration to these intertidal zones may play an important role for some species whilst for others it may be an alternative habitat used as a feeding area and/or as a refuge.

Despite no clear differences in intertidal and sub tidal fish assemblages located at sites with different seascape configurations were found, certain features of intertidal and sub tidal habitats (i.e. wave exposure, inundated area and slope) might differentiate the relative abundance of species among sites. Nevertheless, the differentiation of these effects needs to be carefully evaluated in further studies.

Fish tidal migrations are a commonly overlooked part of the home-range movements of coastal fishes. The importance of this mechanism needs to be carefully assessed in macro tidal areas of the world, such as the tropical eastern Pacific. A better understanding of how these short-term movements operate may benefit conservation efforts directed to ensure the habitat connectivity for fishes within national parks of the region.

Prospects

I finished my master studies with the best grade possible for my thesis project (A). Right now I am preparing two manuscripts derived from the project to be published soon in international peer-reviewed journals. Additionally I am preparing my PhD project (Bremen Universität and Center for Tropical Marine Ecology) related to fish intertidal migrations in other habitats (mangroves) of the Colombian Pacific Ocean and a comparison with similar systems in Brazil.

Publications and Presentations Derived from the Project

Castellanos-Galindo GA, Krumme U., Giraldo A (2008) Tide-related variation in the reef fish fauna of Utría National Park (Colombia, Tropical Eastern Pacific). 11th International Coral Reef Symposium, Fort Lauderdale, USA. (Poster presentation).

Castellanos-Galindo GA (2008) Tides and seascape configuration: determinants of reef fish intertidal migration in the tropical Eastern Pacific. Master thesis, ISATEC Program, Bremen Universität, Germany, 73 p.

Castellanos-Galindo GA, Krumme U., Giraldo A (in preparation) Tidal influence on fish distribution in rocky shores of the tropical eastern Pacific (Colombia). To be submitted to Marine Ecology Progress Series.

Results Dissemination at the Local Level

During fieldwork I had constant interaction with stakeholders of the area. I presented the project to the local communities, fishermen organizations and to the National Park authorities. Throughout the project I had the assistance of a young biologist of the area (Angel Villa), who gained expertise on reef fish monitoring. Additionally, four fishermen joined permanently sampling activities at the four study areas. This interaction led to the identification of common names for reef fish species that are not commonly fished in Utría. The information was further used in the production of an educative poster related to the reef fish fauna of the Utría National Park (see annex). During the Poster production we worked together with the World Wildlife Fund - Colombia, a local University (Universidad del Valle) and the Center for Tropical Marine Ecology in Germany.