2ND INTERNATIONAL SYMPOSIUM ON MANGROVES AS FISH HABITAT

Toning Up Critical Mass for Mangroves Nurseries for Fisheries in Sundarban

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Mangroves serve as an intermediate nursery habitat that may increase the survivorship of young fish. It has proven by research studies that the largest herbivorous fish in the Atlantic, Scarus guacamaia, has a functional dependency on mangroves and has suffered local extinction after mangrove removal. Sundarbans are the world's single largest mangrove biomes having highest mangrove biodiversity. Sundarban is the home to around 172 species of fishes, 20 species of prawn and 44 species of crabs.

Climate Change & Mangroves as Fish Habitat Revisited

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This presentation will focus on issues involving climate change and mangroves. Mangroves play an obviously essential role in enhancing marine life. Mangroves are vital marine nurseries; they protect coral reefs and sea grass beds from pollution and sedimentation; and they are a major contributor to the food chain supporting an immense variety of marine life. Yet, more thought and planning needs to go towards the present day role mangroves are playing and the future role they will play in regards to factors affected by climate change, such as global warming, melting ice caps, and sea level rise, ocean acidification and increased severity and frequency of natural disasters such as hurricanes and storms. As well, we will explore how continuing settlement of human populations and expanding development industries along the coastal regions are affecting the upland movement of mangroves as sea levels rise and inundate coastal zones.

Concepts of vulnerability as drivers of conservation priorities: an applied study of fish communities in the Galapagos Marine Reserve

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Marine biodiversity can be protected by identifying vulnerable species and creating marine protected areas (MPAs) to ensure their survival. We applied two species vulnerability assessments, the IUCN red list of threatened species and FishBase’s intrinsic vulnerability assessment, to fish communities in three coastal habitats (mangrove, rocky and coral) on the island of San Cristobal, Galapagos. When using the IUCN red list, rocky reefs hosted the greatest number of vulnerable species, however when applying the FishBase assessment of intrinsic vulnerability mangroves hosted the greatest abundance of vulnerable species. This study demonstrates that the FishBase vulnerability assessment is the appropriate measure to use in the Galapagos Islands because the high level of endemic species determined vulnerable by the IUCN red list creates an overly inclusive recommendation based on rarity, rather than prioritizing species with key functional roles in spatially limited habitats. Mangroves are a limited habitat type in the Galapagos Islands that merit special conservation consideration as habitat for vulnerable fish species. Vulnerability assessments based on intrinsic factors are not widely applied in marine spatial planning, but their inclusion as a tool for forming conservation strategies can be useful in preventing species loss, particularly in areas with high endemism.
Restoration of sustainable artisanal fisheries through community based conservation of mangrove forests along the Sindh Coast, Arabian Sea, north Indian Ocean, Pakistan

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Mangrove forests along Pakistani Sindh's coastal belt have been vanishing rapidly due to timber extraction, discharge of municipal and industrial effluents, aquatic pollution and coastal development works in Indus River delta region. The changes in mangrove habitat have further been aggravated by drought, scarcity and decrease in freshwater discharge downstream in mangrove coastal areas and estuaries of Sindh. It is estimated that around 104 million gallons of untreated municipal waste, 175 million gallons of untreated industrial waste from Metropolitan City of Karachi is discharged in the mangrove habitat every day.

Fish and mangroves, functional restoration in the Yucatan Peninsula

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Los manglares brindan múltiples servicios ecológicos, para los peces existen 2 hipótesis que explican su distribución 1) son zonas de crianza y resguardo y 2) son sitios que proveen gran cantidad de alimento. Los manglares son guarderías para especies de importancia comercial y ecológica que regulan procesos de transferencia de energía y nutrientes con sistemas adyacentes. En proyectos de restauración ecológica pocas veces se mide el éxito por medio de indicadores como diversidad o estructura trófica, por lo tanto, el objetivo es determinar la función de protección y alimentación que brindan los manglares a los peces, evaluando composición y abundancia de especies, además de su nivel trófico en diferentes sitios de restauración. Se realizaron 6 muestreos en canales de 4 sitios restaurados de manglar en Yucatán con trampas y red de arrastre. Se registraron 23 especies, siendo Gambusia yucatana la más abundante y especies como Bairdiella chrysoura, Sphoeroides testudineus, Anchoa mitchilli y Mugil cephalus, especies vectoras en la transferencia de energía y nutrientes a sistemas adyacentes. Especies dulceacuícolas como Cichlasoma urophthalmus, Poecilia velifera y Belonesox belizanus fueron registradas. La presencia de niveles tróficos altos, comprueban la restauración de al menos una cadena trófica en el ecosistema de manglar.

Role and quality of refuge habitats for Everglades fishes: coastal natural vs. wetland artificial?

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In tropical pulsing systems such as the Florida Everglades, seasonal hydrology creates a temporally-variable habitat mosaic that influences patterns of fish abundance and distribution across both coastal and freshwater habitats. In response to this seasonal variation in habitat availability and quality, fish move into deeper or refuge habitats, but little is known about their relative quality. We compared the quality of coastal mangrove creeks and inland manmade canals as refuge habitats for key marsh mesoconsumers displaced in the dry season: Largemouth bass, Florida gar and bowfin. We compared their performance to resident common snook in creeks and resident nonnative peacock bass in canals. We assessed variation in patterns of abundance, size distribution, body condition, and extent of the habitat use using electrofishing and tagging techniques. Bass and gar were more abundant in canals, but were larger and in better condition in creeks. Displaced freshwater mesoconsumers were two to five times more abundant than resident snook and peacock bass. Results suggest tradeoffs in habitat quality that likely influence the movement
decisions of fishes, and highlight the importance of refuge habitats to population and recolonization dynamics in pulsing systems. We discuss results in the context of climate and implications for recreational fisheries.

Loss of Coastal mangroves on the Island of New Providence, the Bahamas

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The Mangrove forests, formerly called the swamp lands, of the Bahaman islands have been subjected to needs of a growing population and have been lost in the face of unsustainable development. These areas are historically prime real estate for development: filled in to create land, dredged for marinas and fragmented for roads. These areas are also utilized for fishing. The functionality of these degraded mangroves is reduced and habitat for fish is diminished as well. These mangroves function as a nursery habitat for the reef fish surrounding the islands of the Bahamas and protect the investments of those who utilize these areas. A reduced fish habitat impacts the overall quality of the fishing industry. Given the important nature of these habitats each time the ecosystem is degraded the fishing industry feels the impact; albeit long term. The island of New Providence is no different. The city of Nassau houses roughly 2/3’s of the Bahaman population. The island of New Providence has seen many key mangrove habitats destroyed, fragmented and degraded during this time. The combination of habitat degradation, increased populations and increased fishing pressure over the last 50+ years has impacted the quality of the fish on the reefs surrounding New Providence. This presentation aims to quantify the area of fisheries habitat lost on the island of New Providence as a result of unsustainable development and show projects and programs that aim to change the fate of these ecosystems.

Assessing mangrove habitat complexity and its implications for fisheries

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One of the paradigms in mangrove ecology is mangrove’s role in sustaining coastal fisheries through the provision of nursery sites for nekton. Assessment of this service of mangroves has, however, been hampered by the lack of satisfactory means for realistically assessing the protective role of mangrove vegetation structure to juvenile fish, and how this service may vary in relation to mangrove species and forest conditions. We developed a simple and low-cost method for assessing mangrove habitat structure and complexity at spatial scales relevant to benefits that juvenile fish may derive from the habitat, particularly, protection from predators and increased food availability. This method also opens up opportunities for manipulative experiments to test specific hypotheses concerning the role of mangroves as nursery sites for juvenile nekton.

Biogeography of mangrove fish assemblages in the Neotropics

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Mangrove forests in the Neotropics represent ca. 28% of the world mangroves and are distributed in a variety of settings including micro- to macrotidal regimes, low salinity to hyper-saline areas, extremely rainy to arid conditions and diverse adjacent seascapes (muddflats, seagrasses, coral-rocky reefs). Studies in the past have not acknowledged that the environmental variability in settings and biogeographical history of the region can greatly influence the composition of mangrove fish assemblages. Here, we present a meta-analysis of >40 studies on mangrove fish assemblage composition from 5 provinces where mangroves occur in the Eastern Pacific and Western Atlantic Ocean. In provinces where coral-rocky reefs do not occur, fish compositions reflect the ancient geological links of these regions (sites dominated by e.g. Ariidae, Tetraodontidae). In contrast, in provinces where coral-rocky reefs occur in close proximity to mangroves, the seascape configuration seems to play a more important role in
determining fish compositions (e.g. dominance of Lutjanidae, Haemulidae). Accounting for the influence of biogeographical history and seascape characteristics will (1) benefit our understanding of the different roles of mangroves as fish habitat in different regions of the Neotropics, and (2) help defining the limits to generalizations of mangrove functioning across and within regions.

Colonization of Robinson Preserve: An Evaluation of Restoration Efforts in an Estuary in Tampa Bay, Florida

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Florida’s coastal habitats have been severely impacted by development, with some areas experiencing mangrove habitat loss of over 80%. In the past 100 years, Tampa Bay has lost over 44% of its mangrove and salt marsh habitat. Robinson Preserve is a 197-hectare preserve, located on the southern shore of Tampa Bay. Originally a coastal wetland, the property was ditched, drained, and used for agriculture. In 2006, over 450,000 m3 of soil were moved to restore tidal flow. While upland and salt marsh vegetation were planted, aquatic flora and fauna were left to colonize from neighboring populations. The waters of Robinson Preserve were sampled quarterly from 2007-2013 to evaluate the success of restoration activities. Different species colonized the preserve at different rates based on life-history characteristics, with some species being seasonal. Within the first year following tidal reconnection, 18 fish and 14 invertebrate species had been collected. Although the rate of colonization slowed, at least one new species was documented during each subsequent sampling event. After 7 years of colonization, 85 fish and 105 invertebrate species have been observed. Numerous commercially or recreationally important species utilize the preserve for juvenile refuge and/or adult foraging (e.g., snook, red drum, seatrout, tarpon, and mullet).

Climate extremes create legacies on tropical floodplain fish subsidies in a mangrove coastal river

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Extreme and episodic droughts may alter tropical floodplain prey subsidies to river fishes by reducing seasonal floodplain inundation regimes affecting floodplain communities. These impacts may change the dynamics of floodplain subsidies to river fishes, as impacted floodplain communities reset and recover to a pre-disturbance state. In 2011, an episodic drought impacted coastal rivers in the southern Everglades. This drought likely altered Everglades marsh floodplain fish communities that function as important seasonal fish prey subsidies to snook living in adjacent coastal rivers. From 2010 to 2013, we sampled the abundances and diets of snook within the Everglades floodplain-river interface monthly. Our results show that one year after the drought in 2012, marsh floodplain sunfish subsidies were largely absent. Two years after the drought, sunfish biomass entering the coastal river tripled relative to pre-drought conditions, but were packaged differently, such that the average body size of sunfish prey doubled. Despite the increased magnitude of sunfish subsidies, the consumption of floodplain biomass did not differ from pre-disturbance conditions. With increases in the frequency of climate extremes like droughts, we may expect the year to year predictability of floodplain subsidies to decrease, which will likely alter their role in provisioning river fisheries.

The Effects of Spawning Behavior on a Data-Poor Assessment of a Spawning Aggregation Fishery

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We used several data-poor techniques to investigate the possible effects of gear regulations and age-dependent variation in spawning frequency on assessments of a spawning aggregation fishery for the Gulf corvina (Cynoscion othonopterus) in the Gulf of California, Mexico, during the period of 1998 to 2012. Assessments using length-based
metrics suggested that the fishery exceeded biological reference points for sustainability during most years and benefited from the implementation of a regulation that standardized the mesh size of gill nets used in the fishery. Modeled estimates of spawning potential ratios (SPR) were higher when spawning frequency was assumed to be age invariant and were significantly higher after the implementation of gear regulations. However, SPR values only exceeded targeted reference points during the current fishing period under conditions of age invariant spawning frequency. Differences in the conclusions drawn among the various analyses demonstrate the need to incorporate multiple assessment methods in data-poor situations. This study provides further evidence that estimates of reproductive potential are highly sensitive to age dependent variation in spawning frequency, and it suggests that details related to spawning behavior require more attention in stock assessments, particularly for fisheries that target spawning aggregations.

Small-scale fishery within a lagoon system in the Gulf of California

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Mangroves are located in the transition between water and land. They are one of the most productive ecosystems due to their high organic matter and nutrients flow to adjacent environments. There is a direct relation between commercial fish exploitation and mangrove environment. We assessed the interaction between mangrove cover with small-scale fishing volumes in the last 17 years in the San Ignacio–Navachiste–Macapule lagoon system. We also related fishing captures with fishing gears, catch was processed and spatially represented in a Geographical Information System that identified fishing sites within the lagoon. From 2000-2009 the total fishing average was 56,434t with an annual capture of 11,287 ±1,887.5t/year. Shrimp and crab represent 90% of the total capture with an annual production of 22,733t ±1632.07t /year. Fin fish and shell fish had a low catches. 47 fishing points have been processed; we have found 127 fishers that use different gears: hooks, crab traps, set and draft gillnets and two types of castnets. The latter two gillnets are the most used fishing gears in the lagoon with 32 and 23% respectively by fishers. The main fish species are captured close to mangroves suggesting a strong relationship between mangroves and captures within the lagoon.

Coastal wetlands as fish habitat in Marismas Nacionales, West Mexico

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We present a Marismas Nacionales hydrological regionalization, including continental watersheds draining into the Pacific Ocean from the Sierra Madre Occidental -rivers: Baluarte, Buñigas, Las Cañas, Acaponeta, San Francisco, Rosamarada, San Pedro, El Tanque and Santiago- and from the Trans-Mexican Volcanic Belt -rivers Mololoa, Navarrete, Sauta, El Palillo and La Tobara-, and tidal basins flooding low-lying (intertidal) coastal areas with seawater -inlets: La Guanera, Las Islitas , El Borrego, El Vigia, El Rey, Segada, Los Baños, El Asadero, El Sesteo, Camichín, El Colorado, Cuautila, Teacapán, and Chamelita-, between Matanchén (San Blas, Nayarit) and Chametla (Rosario, Sinaloa). It also describes both constructions and activities developed and planned to produce hydroelectric power and divert water in these inland basins and to seize the tide ebbs and flows for productive purposes. It posed a classification of aquatic and wetland habitat for fish and other animals and plants, describing their potential relationships with continental and tidal flows in their various combinations. Finally, it raises the challenges facing aquatic and wetland habitats and their organisms to the constructions and activities described. It concludes with recommendations regarding the constructions and activities referred to above.
Site fidelity and homing behavior in the four-eyed fish *Anableps anableps* (Anablepidae): A study in a Brazilian mangrove revealed by radio-frequency identification and visual census

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Knowledge on the intertidal movement of mangrove fish is surprisingly scarce, yet important to understand fish habitat use. The intertidal migration of the four-eyed fish *Anableps anableps* (Anablepidae, Cyprinodontiformes), a surface swimming species, was investigated along two mangrove-lined creeks in North Brazil. We used mark-recapture techniques based on passive integrated transponder (PIT) tags implanted in 270 individuals to investigate site fidelity into specific creeks and test if the fish exhibited homing behavior when re-located to a foreign creek. External tags were used to study their subtidal home range. Recaptures took place sporadically from December 2011 to March 2013. A total of 95 individuals (35%) showed site fidelity to a specific intertidal creek. Low water observations revealed that individuals (84%) were located in front or 100m from their home creek. A cross-transplantation experiment between the creeks (875m apart) revealed the ability of the species to return to the original creek of capture within 12 days (30% recapture). As fish resources are assumed to be equally abundant thought the mangrove forest, the behavior of *A. anableps* could be the result of intra-specific competition for high quality resources (protein) signifying that mangroves are not homogenous habitats as has long been assumed.

A meta-analysis approach to mangrove-fishery linkage

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Mangroves are one of the most productive ecosystems in the tropical and subtropical regions where they grow and settle in protected estuarine systems. Mangroves support high diversity of terrestrial and marine fauna despite coping with fluctuating environmental conditions. However mangroves have been heavily removed for aquaculture and agriculture among other anthropogenic activities. Historically, mangroves are believed to support artisanal fisheries leading decision makers to protect mangroves based on this premise. However this relationship remains controversial despite positive correlations obtained in different geographical regions. To date no meta-analysis approach has been carried out to quantify the mangroves-fisheries linkage at a global level. A systematic review is being done, so far 13 publications containing 29 studies estimating coefficient correlations (r) have been included. Different fisheries such as prawns, fish, crab and total catches have been analyzed across the world. A random effect model was used to estimate the effect size of each study and the total effect size of the outcome. Most effect sizes were positive and significant (i.e. different from cero) and the overall effect size was 0.73. The fail-safe number analysis together with the effect size suggests that mangroves worldwide are important to support fisheries as mangroves provide critical habitats.

Mangrove restoration in Sinaloa: ecological dynamics to assist in maintaining fisheries

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El estado de Sinaloa se ubica en el noroeste de México, alberga nueve ecosistemas lagunares-estuarinos reconocidos como sitios RAMSAR. En ellos se encuentran aproximadamente 80 597 ha de ecosistemas de manglar. A nivel mundial viven, se alimentan y se reproducen cerca de 840 especies con importancia pesquera. En la zona
costera de la entidad se localizan 154 comunidades pesqueras que viven de la captura de especies como: escama marina, camarón, jaiba, ostión, tiburón, calamar y langosta. Sin embargo, el azolvamiento y actividades como el turismo, acuicultura, caminos y agricultura causan deterioro a estos ecosistemas. Derivado de lo anterior, la Facultad de Ciencias del Mar-UAS en colaboración con el Instituto de Ciencias del Mar-UNAM Unidad Mazatlán han desarrollado diversos proyectos de investigación, con el fin de afinar y proponer estrategias para la restauración de manglares, de los cuales destacan los realizados en la bahía de Navachiste donde se crearon aproximadamente 6 has de nuevas áreas de manglar en isletas de dragado, en el sistema Huizache-Caimanero se reforestaron aproximadamente 60 ha de manglar y se reestructuró la hidrología de algunos sitios del sistema. En este mismo sentido se ha trabajado en los esteros de Urias y Teacapán.

**Primary producers and their relationship to sedimentary organic matter in Terminos lagoon and continental shelf**

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Anthropogenic activities and climate variability in Terminos Lagoon and adjacent continental shelf generate effects on spatio-temporal distribution of primary producers. To determine the relationship between the distribution of primary producers and composition of sedimentary organic matter (SOM) are compared δ13C data of the present study (2011) with data reported in 1991 and 2004. The contribution of primary producers to the SOM was estimated using the model SIAR. The contribution of the mangrove to SOM, no significant difference between 1984 and 2011 with contributions of 38%, and 35% respectively. The contributions of seagrass, phytoplankton and macroalgae were significantly different. A decrease of the contribution of seagrasses in 12% between 1984 and 2011, was related to the decrease in the seagrass coverage during last 30 years in Terminos Lagoon (P <0.05, r = 0.92). The results confirm that the degree of contribution of primary producers to SOM is related to the coverage of vegetation in the lagoon. The mangrove contribution to SOM has little change in the last 3 decades, being an important component of the export material of the lagoon system toward the adjacent sea, while the contribution of seagrass tends to decrease as a result of the loss in coverage.

**Sealevel Rise Impacts and Its Implication on Mitigation & Adaptation of Mangrove Ecosystem in Indaramayu, West Java**

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This research aims to identify local vulnerability indicators, assess the impact and formulate mitigation and adaptations of mangrove ecosystem to sealevel rise. Mangrove in Java have had significant changes in the last 20 years, after extensively being misused as shrimp ponds and subsequently abandoned in the early 90's; some of the mangrove areas have been recovered naturally or by rehabilitation programs. However other threat also occurred lately, Northern Java coast have been facing many problems brought mean sealevel rise and other climate change impact in the last twenty years; this is easily recorded by the acceleration of abration, tide-wave and flood in the area. All of these stresses will endanger mangrove, aquatic biodiversity, secondary production, and finally the community livelihood and income. This study on the impact of ecology on 2 different ecosystem mangrove in the delta of cimanuk showed that the enclosed/protected ecosystem has higher mangrove cover, biodiversity, and
secondary productivity compare to that the open coast; but lower on abration level, saltwater intrusion and secondary production. In searching for strategies to increase the ecosystem resiliency, 4 programs are recommended for indramayu: greenbelt establishment, mangrove conservation, coastal fishing control and alternative aquaculture development.

**Status of Mangrove Biodiversity and Conservation in the Typhoon-prone island of Catanduanes, Luzon, Philippines**

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Catanduanes Island is located in Luzon, Philippines (Lat. 13.67°, Long. 124.12°) and found in the “typhoon highway” in the North Philippine Sea of the Pacific. Coastal portions of the island are exposed to vital marine bodies with the typhoons that pass in the island. Municipalities, west and east of the island are less industrialized and less urbanized. Therefore coastal biodiversity are not yet under much deterioration. But recent natural disasters and conversions of mangrove areas into aquaculture and industrial sites have added threats. At other parts of the island is relatively safe and rich. The Catanduanes State University of the island is engaged in the census of coastal life in Catanduanes. However, due to lack of a long-term program on coastal biodiversity, research capabilities, support facilities, research funding and regular communication with the Philippine National Museum, etc., still many gaps exist regarding the survey. Till now diversity of macro benthos have been assessed partially and the need for further inquiry and conservation. The paper reviews thoroughly the work done till now on census of coastal life in Catanduanes, the analysis of the different mangrove conservation programs using a scheme known as SID-SIN-SEN [Stakeholder Identification (SID) - Stakeholder Inputs (SIN)- Stakeholder Engagement (SEN)] developed by the university (OCMA article, in Revision) and suggest measures for its protection and biodiversity conservation. The need for a reference collections unit for a small Museum of Natural History in the university is needed at the present time to include the early to late Cretaceous Ammonites obtained in the island for paleobiosystematics in Asia.

**Predicting the effect of MPAs on nearby ecosystems: Habitat connectivity of seagrass bed and the protected mangroves as shown in the intertidal molluscan diversity and fish assemblage in atanduanes, Philippines**

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Seagrass beds are extensive shallow-water habitats in the Philippines, but few reports have assessed the extent to which gastropods and fish assemblage explain the source-sink theory. This can contribute an understanding of the function of mangrove protected areas as population sources. Mangrove reserves are favoured as a management tool maintaining good quality and rich habitat and thus improving population connectivity by enhancing larval supply and recruitment in neighboring habitats as the seagrass beds in Philippine shores. As claimed by many researchers recent advances in the study of protected areas in the context of the source-sink theory remains largely unexplored. This student-faculty study investigated the role of a mangrove protected area as population sources by looking into whether there is mirroring beyond the reserve boundaries and investigated whether the gastropods and bivalves are segregated from or integrated with fish from seagrass beds. Field surveys by visual census were carried out to describe bivalve-gastropod abundance and diversity indices together with the fish richness in the seagrass beds compared to that in the protected areas at two locations in Catanduanes Island. Diversity of juveniles and adults of fish species were recorded and segregation of bivalve-gastropod molluscs were described. Based on the richness and abundance a discussion is hereo presented as to the predicted notion that recruitment would mirror adult abundances that the mangrove reserves may act as important refuges. Moreover, a discussion on habitat segregation among life stages of some nursery species of bivalves and molluscs may be responsible for habitat segregation of fish species, life stages and feeding groups.
Selecting potential restoration sites based on carbon sequestration estimates of red mangrove flats in the Bahamas

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Mangrove ecosystems are being lost globally at an alarming rate due to deforestation, reclamation, and urbanization. Not only is the loss of these ecosystems detrimental to commercially and ecologically important marine species they support such as bonefish (*Albula vulpes*), there is also a reduction in the ecosystem services they provide, namely mitigating rising carbon dioxide levels by serving as carbon sinks. These ecosystems, labeled as “blue carbon” sinks, potentially sequester more than ten times the carbon that tropical and temperate ecosystems do. Thus, conservation and restoration of these blue carbon sinks is imperative. When it comes to restoration, it is important to select sites that will not only serves as vigorous fish nurseries, but will also potentially sequester the greatest amount of carbon at the greatest rate. A long-term study was initiated in January 2013 on Eleuthera to determine the factors that lead to the greatest carbon sequestration of red mangrove (*Rhizophora mangle*) flats. Carbon pool and sequestration rates were estimated at four study sites and correlated to environmental variables. The variables that had the strongest correlations with carbon sequestration become predictors for the most suitable restoration sites in the future.

Spatial and temporal variation of fish assemblage associated with mangroves in a coastal lagoon of Cayo Coco, Cuba

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This study examines the variation in time of abundance and biomass of fish in a mangrove channel located in Laguna Larga, Cayo Coco, Cuba. The channel was divided into two zones of 100 m and separated by a distance of 30 m. The number, size and behavioral notes for all fishes were estimated using a visual census technique in free diving for three years. Was estimated shadow and refuge area in the channel. The density and biomass were calculated. 52 fish species were identified from 31 genera and 24 families. The most abundant species were: *Abudesuf saxatilis, Halichoeres bivittatus, Lutjanus griseus* and *Stegastes leucostictus*. The communities of mangrove fish in the studied vary space and temporarily. The observed space variations are due to the characteristics of the habitat and the distance between the channel and the open sea. The temporary variations seem to be related with the mobility, reproduction and recruitment of the fish. The main variation time scales of fish are the months, followed by the seasons. This supports the need to take into account in studies of these variations over time scales small areas and so particularize the management of natural resources for each site in question.

Habitat zonation and fish assemblages between and within three adjacent coastal tidal creeks on Cape Eleuthera, The Bahamas: Implications for monitoring and conservation

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In this study, three adjacent creek systems (Page, Kemps, and Broad Creek) along 3km of coastline on Cape Eleuthera were studied to understand the variation in habitat and fish community structure in systems with similar climactic and geologic influences. Paired snorkeling data were collected on a summer new moon during slack high
tide and involved the simultaneous assessment of each creek, replicated over a three day period. Despite their close proximity, creeks differed in habitat and fish community structure. However, even greater variation was observed within creeks. Zonation was apparent between the mouth and more inland regions (i.e., middle and upper) portions of each creek. Larger sediment was found near creek mouths due to the increased energy of wave action. Macroalgae (e.g., dasycladus) tended to predominate in upper regions whereas seagrasses (e.g., thalasia, halodule) were more dominate towards the mouth. Within each creek, mangroves had the most diverse fish assemblages, followed by algal plains, sand plains, seagrass, and somt sediment. In all creeks, significantly more fish were observed in the mouth compared to the upper zone. While Kemps Creek had a slightly lower Shannon-Weiner diversity index, there was no significant difference in the richness or abundance of individuals observed. Collectively these findings reveal that conservation and management strategies as well as monitoring programs must recognize that habitat and fish assemblages between and within tidal creeks can vary extensively over relatively small spatial scales.

Mangrove Protection in the Bahamas and United States: A Comparative Analysis

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The paper compares mangrove protection laws in The Bahamas and in the United States. The Bahamas was one of the first signatory states to the United Nations sponsored Earth Summit in 1994. This popular Convention is widely heralded as the international community's most vocal recognition that biodiversity conservation is critical to the survival of humankind. Convention signatories were also required to create national biodiversity action plans. Following the Rio Conference, The Bahamas National Trust created a National Conservation Strategy for the islands. The Prime Minister of the Bahamas then announced the creation of the Bahamas Environment, Science and Technology Commission to among other things review and coordinate policies and to develop strategic planning on environmental protection, including mangrove protection. Mangrove protection is vital in The Bahamas in that they provide nursery habitats for marine life, minimize flooding and soil erosion, serve as carbon sink holes, and more generally are vital to biodiversity in The Bahamas. This paper compares mangrove protection in The Bahamas and in the United States by assessing the extent to which each country's laws are guided and informed by scientific data; how each country navigates local versus national laws and interests; the level of interagency coordination; and the extent to which each country funds mangrove protection.

Recreational Fisheries as Conservation Tools for Mangrove Habitats

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Habitat degradation and loss are among the top causes of fisheries declines worldwide. Mangrove habitats are among the most threatened coastal habitats, and are lost at a rate of xx per year, and are vulnerable to sea level rise associated with climate change. Loss and degradation of mangroves have broad impacts because mangroves are important in prevention of coastal erosion, excellent at carbon sequestration, and are critical habitats for terrestrial, estuarine, and marine vertebrates and invertebrates. Mangroves are essential habitat for many marine and estuarine fishes, including coral reef and even offshore species. However, these species often lack the economic importance to leverage conservation of mangrove habitats. Ongoing research is demonstrating the importance of mangrove habitats to economically important recreational fish species which, in conjunction with reports on the economic impact of these fisheries, provides leverage for mangrove conservation. Three recreational fish species – common
snook (*Centropomus undecimalis*), Atlantic tarpon (*Megalops atlanticus*), common bonefish (*Albula vulpes*) – depend on mangrove habitats for one or more of their life stages. Each species also supports fisheries with economic impacts of hundreds of millions of dollars. The combination of biological and economic research allows recreational fisheries to be used as tools for mangrove conservation.

**Building a global model of mangrove fisheries value**

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The importance of mangroves for fisheries is well known, but there has been little work to quantify the factors underpinning fisheries value. In particular, no one has attempted to investigate drivers and spatial variance on anything more than a local scale. We carried out a systematic search of the primary literature on mangrove fisheries, which returned over 1500 papers. We analyzed 170 of the most relevant of these, and extracted mangrove fisheries catch data for almost 100 sites around the world. We also extracted data for potential drivers of variability in both catch and value, including human population density, GDP and mangrove biomass. From these data, we will model mangrove fisheries value, and particularly the spatial variability of such values. Initial models will be simple, conceptual efforts, but we also hope to develop numerical models for key species groups such as crabs and prawns, which will enable us to predict expected catches in tonnes per hectare of mangrove area. Here we present some initial findings, and the challenges arising. Ultimately this will feed into a wider suite of work quantifying the multiple ecosystem services mangroves provide, aimed at cutting mangrove loss, improving management and encouraging restoration.

**Intertidal fish community structure in mangrove-lined and unvegetated creeks of Qeshm Island, Persian Gulf**

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The role of mangroves shaping intertidal fish communities on arid coasts is little understood. Spatial changes in fish community structure were studied in natural 4 mangrove-lined and 2 adjacent unvegetated intertidal creeks from an arid, non-estuarine system in Iran, Persian Gulf. A total of 5954 individuals from 29 species (22 families) were caught in the mangrove-lined and 2467 individuals from 22 species (18 families) in the unvegetated intertidal creeks. The detritivorous *Liza klunzingeri* (Mugilidae) dominated abundances and catch mass in both sites, followed by *Anodontostoma chacunda* (Clupeidae) in the unvegetated site, while in the mangrove creeks zooplanktivores (*Leiognathus daura, Thryssa vitrirostris*) and macrobenthivores (*Pentaprion longimanus, Acanthopagrus latus, Lutjanus johni*) had larger shares. Mean fish density and biomass were relatively low (0.05 fish m⁻³ and 0.6 gm⁻³ in the mangrove creeks, 0.01 fish m⁻³ and 0.2 gm⁻³ in the unvegetated creeks). The overall low biomass, density and species richness are likely due to the extreme environmental conditions in this arid region at the northern edge of the Indian Ocean (i.e. salinities >38, seasonal fluctuations in water temperature >20°C, low productivity).The presence of mangroves in this arid region resulted in intertidal fish assemblages with only slightly more species, higher diversity index and evenness compared to bare fish, suggesting that the fish nursery role of mangroves growing under extreme environmental conditions is only minor.
Responses of Mangrove Fish to Climate Change

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Future climate change scenarios for tropical climates are currently predicting an increase in oceanic temperature, an increase in oceanic salinity and a reduction in ocean pH. Many marine organisms appear to be quite sensitive to small changes in oceanic conditions, and, in response to changing oceanic environments, fish can experience energetically costly physiological disturbances, or they may choose to seek more favorable water conditions. Mangrove fishes reside in a dynamic and extreme environment within tropical oceans, and also play vital roles in within the marine community, but their responses to future climate scenarios has received relatively little attention. The objective of this study was to quantify the response of mangrove fishes exposed projected future oceanic conditions, and compare physiological and behavioral responses to these different environments. The water quality parameters used included an increase in salinity, a reduction in pH, elevated temperature, and a treatment that combined both increased temperature combined with reduced pH. Water conditions were manipulated by gradually adjusting ambient seawater in the direction of change that exceeds predictions by the Intergovernmental Panel on Climate Change. Blood samples were taken from each fish and analyzed for indicators of stress, and behavioral responses were also quantified. Results from this experiment will contribute to our understanding of how performance, and ultimately fitness, of these fishes, will change under future climate scenarios, and which facet of future oceanic environments will be the most challenging for mangrove fishes.

Characterization of small-scale fisheries in mangrove habitats of Puerto Pedregal, Chiriquí Gulf, Panama

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Small-scale fisheries represent 95% of fishing activities in developing countries, many associated with mangrove habitat. Despite ecological, cultural, socio-economic and food security relevance, data about fishers, gears, species habitats and economics are mostly inadequate. Improved documentation is needed to assess global trends, identify threats to sustainability and develop effective management. The study was conducted at Pedregal, an important fishing port in Panama’s Chiriquí gulf dominated by mangroves. Data were collected over a four-month period covering one third of the local fisher’s population, combining independent biological surveys and participative methods: (i) Fish species identification, (ii) fisher’s bulletins obtained at landing sites, (iii) structured interviews, and (iv) local fish buyer’s reports. Two structurally different fisheries were identified, representing inshore mangrove (ribereño) and mixed-environment (artisanal) fishers. They typically use multiple boats and gear (5 types of gear employed with 2 boat categories as well as directly from shore), exploiting many species (102 species of interest to the fishers). Fishers perceived declining catches due to external industrial fisheries pressure, as well as inadequate governance. They aspire to participate in resource management. The results are discussed in terms of needs and requirements for developing adaptive, environmentally sustainable small-scale fishery management in mangrove habitats.
Highlights on El Conchalito, La Paz, B.C.S. taxonomic diversity indices, a five years case of study

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El Conchalito is a shallow protected mangrove bay; over the years, its fish community has been studied and various types of fishing arts have been used on each sampling. Due to the limitations of classical ecological indices (Shannon-Winner diversity, Pielou evenness) comparisons can’t be carried out because of differential sampling efforts. Taxonomic diversity indices (\( \Delta \), \( \Delta^+ \)) are supposed to overcome that limitation while implementing real taxonomic information into the analysis. The indices generate one data that can be traced in a proposed range, allowing to locate the taxonomic category where main community changes happen. Results showed a tendency to increase the number of species from July to November, with a sharp drop in January. Higher values of evenness were found in cold months (december-march), which is explained by seasonal reduction of species and a better distribution of abundance. Shannon’s diversity can’t be taken in a conclusive way due to the problem of statistical inference when differing sampling efforts are implied. \( \Delta \) show high variation within months with erratic taxonomic shift in the course of the year; on the other hand \( \Delta^+ \) exhibit a smaller variation (46.5 > x < 60), meaning that structural community changes happens at family level.

A comparison of the trophic structure of Terminos lagoon and continental shelf for three seasons

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Terminos lagoon (TL) and continental shelf (CS) have interdependency by biomass and energy exchange between these ecosystems to be important for reproduction, feeding and breeding of species of commercial interest. In this study the spatial-temporal variability of isotopic niche in the community structure influenced by mangrove habitats and seagrass was determined. This fish was collected in TL and the CS in norths seasons, dry and rainy. Subsequently the isotopic composition (\( \delta^{13}C \) and \( \delta^{15}N \)) of each specimen was determined. He applied the SIBER (Stable Isotope Bayesian Ellipses in R). This fish fauna of the continental shelf adjacent values is richer as (\( \delta^{13}C \approx -15 \% \)) result of a trophic structure based on submerged vegetation. While the fish fauna present Terms Lagoon less enriched significantly different values (\( \delta^{13}C = -24 \% \)) (\( P <0.001 \)). An average difference of 0.7 in the trophic diversity of ichthyofauna in this Terms Lagoon compared with the adjacent continental shelf is observed, finding the Mean distance to centroid (CD \approx 2.8) and the total area of the convex hull area (TA \approx 76) in the rainy season. The CS has a higher trophic redundancy, have lower Mean nearest neighbor distance between species (NND \approx 0.75).

Science-based Mangrove Restoration Techniques for Long-Term Benefits

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Mangrove forests contribute high productivity to coastal estuaries, essential habitat for fish and wildlife, buffers from coastal storms, and carbon sequestration. Mangroves in Sinaloa, Mexico have been reduced by the effect of runoff
from upland rivers, agriculture, and aquaculture. Many mangrove estuaries require restoration that will, in turn, help to increase fisheries production for the benefit of local citizens. Because each mangrove estuary has a unique combination of subtle terrain elevations, upland freshwater inflows, exchange rates with saline ocean water, evaporation rates, and mangrove species, restoration must be applied on a case-by-case basis. We use a case study at the estuarine system of Teacapan, Sinaloa to demonstrate the techniques and steps of determining which approaches will lead to successful long-term restoration. The steps include assessment, prescriptions and planning, restoration implementation, monitoring and reassessment, and adaptive management. Results of the assessment allow development of a fine-scale plan for restoring mangroves through a combination of channeling, natural seeding, planting, and water controls. Monitoring includes determining relative abundance of aquatic resources, as well as carbon sequestered, before, during, and after restoration. We describe each one of these steps as they will apply to this restoration project.

Factors Impacting Regeneration of and Coastal Protection by *Rhizophora mangle*

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Mangroves serve a number of functions in tropical coastal systems ranging from habitat provisioning to coastal protection and sediment trapping. However, mangroves are being lost at a rapid rate from tropical coastlines worldwide. We examined ecological factors limiting natural mangrove seedling regeneration in previously cleared mangrove habitat. Decreased nutrient availability and increased wave energy in cleared mangroves as compared to adjacent intact mangroves affected seedling growth rates and leaf production. Identifying ecological factors limiting natural mangrove regeneration can contribute to more effective mangrove restoration.

Assessing seasonal hyperspectral estimation of leaf pigments for dominant mangrove species of the Pacific coast of Mexico

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Mangrove forests are considered among the most important coastal ecosystems maintaining an ecological balance between the terrestrial and oceanic inter-fluxes. Leaf chlorophyll-a (chl-a) and chlorophyll-b (chl-b) could be used as a biological indicator of plant physiological state since they play key roles in photosynthesis. Consequently, the hyperspectral estimation of pigments could provide critical information in assessing mangrove forest condition. The objective of this study consists of seasonal hyperspectral estimation of chl-a and chl-b from three species of mangrove under non-healthy and healthy conditions in a Mexican lagoon of the Pacific. Results show that the red-edge and the green channels present significant correlations (r=0.9) with chl-a in non-healthy stands during the dry season. In contrast, the rainy season presented lower correlations (r=0.6) for the same trees. Healthy stands did not present a very marked seasonality regarding pigments; however the chl-b was slightly higher during the dry season compared to the chl-a which was higher during the rainy season. Hyperspectral estimations of leaf pigment proved to be more accurate during the dry season in non-healthy stands using the red edge and the green channel. Results from this study will assist future works regarding estimations of mangrove cover using spaceborne hyperspectral data.
Coastal and Mangrove Eco-Tourism in Catanduanes island (Philippines): A menace or a bonus?

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Coastal and mangrove eco-tourism in Catanduanes Island in Luzon, Philippines (Lat. 13.67°, Long. 124.12°) is possible along the eastern, western and southern coasts. Yet, when it comes to developing coastal tourism the coastal areas that are mainly being considered happens to be Igang-Mamangal-Balete and so on. These coasts are far way from major metropolitan cities like Legaspi, Naga, Iriga and Manila. Catanduanes Island for that matter is closer to Tabaco, Legaspi and Naga cities and has good coastline with great potential for coastal tourism. Igang and nearby villages flaunt sea beaches with appreciable marine biodiversity, but appears to be of less easy access with the kind of roads available and the frequency of transport for the local and foreign tourists. In view of this, tourism has to gain momentum in these areas. Some beaches like Puraran in Baras have already established themselves as popular tourist spots especially for weekend picnics. There are many nearby beaches and sea shores which have exotic marine flora (marine macro-algae) and fauna (variety of gastropods, bivalves, corals, sponges, etc.). Excessive tourism can pose a menace to these forms. Thus, there is a need to enhance tourism still be vigilant about the sustenance of marine life. Regulated tourism (ecotourism) can serve both the purposes. Economic status of the villagers should be elevated, at the same time serious threat to marine life should be avoided.

Assessment of sustainability of fishery in a protected area of the Coast of Chiapas

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In this work, we comparatively evaluated the sustainability of small-scale fishing in the Estuary System Chantuto-Panzacola, which is part of the core area of the La Encrucijada Biosphere Reserve, a protected area that is home of a substantial fish diversity and large areas of mangroves. The evaluation was addressed through the use of indicators representing five dimensions of sustainability: economic, ecology-fishery, social, technological and institutional locally. The data to form the indicators were obtained using methods of qualitative and quantitative research applied between 2009 and 2012: field observations, a survey of landings, interviews applied to fishermen, statistical information, compilation and analysis of bibliographic and information of commercial transactions. The results suggest that sustainability is multidimensional (making it possible to incorporate in the analysis several aspects of fisheries) and specific. For fisheries sustainability assessments may be established as a good tool to improve fisheries management, periodic information is required to assess their progress.

Caribbean-wide patterns of reef fish occurrence and abundance in relation to mangrove forest area

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Scientists and resource managers have long sought to understand the contribution of mangrove forests to offshore systems, including the transfer of fishes to seagrass beds, coral reefs, and coastal fisheries. Previous studies focusing on mangrove-dwelling fishes known to migrate offshore with ontogeny have been understandably narrow in spatiotemporal extent, largely due to their restricted, short-term research budgets and methodological differences among investigations. The present study draws on an extensive fish data collection effort that spans reefs throughout the Caribbean Sea from off Florida, USA, south to Ceará, Brazil. Since the effort’s 1993 inception, approximately 49,500 fish surveys from experienced divers using the same “roving diver” technique have been logged. Examined here was variation in the occurrence and abundance of four mangrove-associated fish species in relation to mangrove forest area. Probit, quantile, and ordinary least squares regression was applied to provide broad insight
into the importance of adjacent mangrove forest area for _Lutjanus apodus_, _Lutjanus griseus_, _Sphyraena barracuda_, and _Epinephelus itajara_ on reefs. Results suggested that, after accounting for latitudinal effects, mangrove habitat area has the potential to be a primary driver of fish occurrence and/or abundance depending on species. A focus on patterns within Florida waters is also provided.

The conservation implications of spatial and temporal variability in the use of Caribbean tidal mangrove creeks by transient predatory fishes

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The role of mangrove creeks as feeding grounds for transient predators is poorly understood. This study used video cameras to investigate the use of three Bahamian mangrove creeks by transient predators. Over 500 fishes were recorded, comprising of ten species. Linear mixed-effects models demonstrated that sightings of _Caranx ruber_ and _Negapnion brevirostris_ varied significantly among the three creeks. Furthermore, _C. ruber_ was seen most frequently close to high tide, while _N. brevirostris_ was seen more frequently later in the day. _C. ruber_ is presumed to feed in creeks opportunistically when high tides facilitate foraging. Diel and tidal variations by _N. brevirostris_ may relate to crepuscular foraging and predator avoidance in nursery areas. _Sphyraena barracuda_ and _Tylosurus crocodilus_ were seen most frequently just after low tide. All three creeks appear to be critical foraging grounds and refugia from predators for these two species, so they re-occupy this habitat as soon as the water is sufficiently deep. 4. Species-specific spatial variability in creek use demonstrates that simply including representative habitats in marine protected areas could exclude functionally important areas. Furthermore, development that alters tidal cycles in creeks is likely to have significant impacts on transient predators.

Puffed and bothered: the effects of stress on the behaviour of a mangrove-associated fish, the checkered puffer (_Sphoeroides testudineus_)

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Fish are known to exhibit individual differences in “personality”, that is, structured variation in their behaviour that is consistent across time and context. An individual’s personality can affect it’s fitness as well as the role it plays in its ecosystem, potentially contributing to important population characteristics such as dispersal and niche characteristics. Stress is also known to alter the expression of behaviour (and therein personality) in fishes. To determine how the personality of checkered pufferfish (_S. testudineus_) affected by stress, we exposed individual fish to several threat response tests at three time intervals to assess consistency in their behaviour. In addition, we experimentally manipulated cortisol levels, a stress hormone, in some puffers using intra-muscular injections. Cortisol remains elevated for ~3 days at levels comparable to those that can be induced by exposing fish to exhaustive exercise. We compared behaviour before, during, and after the treatment to assess its impacts on personality relative to controls. Our results indicate the extent to which threat-related personality traits can vary in checkered puffers and reveal how elevated stress levels can modulate behaviour. With mangrove ecosystems subject to loss and degradation around the globe, it is necessary to understand how residents will be influenced by associated stressors.

Mangrove Restoration Efforts within the Arabian Peninsula

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Mangal habitats occur at suitable sites along the southern and western coastline of the Arabian Gulf, and at suitable locations along the Red Seacoastline. The mangroves of the Peninsula are at their most northern latitudinal limit and only two species occur \((\textit{Avicennia marina} \text{ and } \textit{Rhizophora mucronata})\). In historical times mangrove vegetation was so abundant that timber harvested in mangrove areas was reportedly used for boat building by the Dilmon people (present day Bahrain). With increasing aridity, impacts from grazing and coastal development, mangal habitats of the Arabian Peninsula have suffered steep declines (>90 %). Recent efforts to restore mangroves have been undertaken throughout the Peninsula with significant success. This paper will cover an overview of mangroves in the Arabian Peninsula and detail mangrove planting projects undertaken in recent years including lessons learned during these projects.

**Processes affecting movement and survival of a juvenile fish in mangrove creeks**

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To improve understanding of the use of mangrove creeks as a juvenile fish nursery, I conducted a mark-resighting study of \textit{Centropomus undecimalis} in Charlotte Harbor, Florida, USA. During a three-year study, I marked 1,917 juveniles, resighting 85.7% with a telemetry array in four mangrove creeks. Emigration rates and survival varied seasonally with lowest emigration rates in the coldest months, and lowest apparent survival in the spring. Emigration events during the fall and winter tended to be temporary movements, while emigration in the spring to summer resulted in more permanent emigration. I interpret this as a potential seasonal transition to alternative habitats, with increased mortality at the end of age-0 acting as an early population bottleneck. Additionally, I found that anthropogenic habitat alterations may act as a thermal refuge during ‘cold kill’ events, and that juveniles spatially segregate from adults to reduce inter-cohort cannibalism. I suggest the mangrove creeks function as part of a habitat mosaic with bidirectional movements being common and seasonal nursery valuation being necessary. Future fish studies in mangrove creeks should consider the role of seasonal dynamics and multidirectional movements, while identifying the casual drivers of movement.