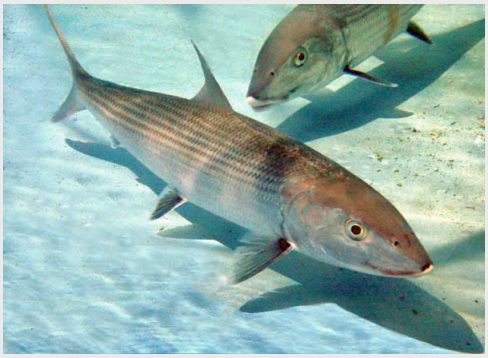
Sport Fish Distribution And Conservation In Belize

April, 2010



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Funded By
PACT
Protected Areas Conservation Trust

ECOWORKS

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Acknowledgements

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Maps Presented

Overview

The following report represents the first deliverable in a series of works funded by the Protected Areas Conservation Trust (PACT) designed to identify potential development threats and impacts on Belize's sport fish population (specifically the country's Bonefish, Permit and Tarpon stocks), and to develop recommendations as to how these potential threats and impacts might be wholly or partially mitigated. The data presented herein is entirely anecdotal, having been summarized from a number of independent reports, but also provides a framework for structuring future research. As such, the report represents a low-resolution overview of where these stocks are distributed; how their respective life-history stages are likely to be specifically and/or relatively impacted by fishing practices and habitat degradation; areas of needed research; and the types of amendments to Belize's regulatory framework that are likely to be needed to mitigate these impacts.

The recommendations presented herein, however, are not written or intended to be final or absolute, but rather a first step in the process of regulatory reform designed to maximize the preservation of these ecologically and economically important stocks for posterity. As such they will be subjected to a lengthy process of stakeholder review and amendment (a portion of which will be funded under the current project) that will hopefully result in the mitigation intended through regulatory amendment.

Economic And Regulatory Background

Belize presently enjoys world-class recognition for Bonefish, Permit and Tarpon fishing, offering the prize potential of a Grand Slam for the landing of all three species in one day. In Belize, there are at least 13 fishing lodges that offer package rates (ranging in price from $4,000 to $8,000 per week); more than 100 Independent fishing guides (who charge daily rates from $200 to $700 each). Fedler & Hayes (2008) established that sport fishing for these three species in Belize (alone) generates a gross annual revenue of USD $28 million, therein creating USD $15 million in annual wages that support 1,800 full-time jobs for Belizeans; and that annual sport fishing revenues might meet or exceed USD $300 million by the end of the forthcoming decade alone, assuming appropriate management arrangements are put in place.

The advent of eco-tourism in Belize however, has resulted in greater demand for waterfront land at the cost of mangrove and sandy beach habitat degradation, which are important recruitment sites for the three sport fish species being reviewed by the present study. This single event, has significantly broadened the administrative responsibility for Belize's sport fish populations to include, in addition to the Fisheries Department, the Forest Department, the Petroleum & Geology Department, the Lands Department and the Coastal Zone Management Authority and Institute, as these statutory bodies have the responsibility of administration of the underlying Fisheries, Forestry, Mining, Lands and Development Acts that govern allowable and prohibited practices in Belize's costal zone, and hence, in critical sport fish habitat. Moreover, it is the loss and/or misuse of such critical marine habitats that will cause fisher-folk to lose fishing income and once again re-direct their livelihood toward the capture of reef fishes from the Belize Barrier Reef, thereby compromising its long term sustainability.

There are presently 8 legally enshrined marine protected areas (MPA's), 11 reef fish aggregation sites, 2 marine natural monuments, and 1 marine national park, or 22 formally recognized marine protected areas in Belize, all of which are associated with the Belize Barrier Reef and/or Belize's offshore faro reef systems. These protected areas have to date largely focused on issues relating to the conservation of the Belize Barrier Reef, its associated reef faros, select coral species, and the connectivity between mangroves and reef-associated species.

More recently, Belize's MPA's have focused on secondary or indirect threats to Belize's reef systems such as the commercial and artisanal extraction of edible reef fishes (e.g. Grouper, Snapper, Parrotfish, etc.), through development of sustainable tour-guiding skills as an alternative livelihood for fisher-folk.

Belize's sport fishing industry on the other hand, now more than 30 years in development; along with the species and habitats on which the industry depends, were never envisioned to be specific conservation targets of the country's marine protected areas program, at least beyond their serendipitous benefit. As a consequence then, it follows that sport fish distributions should also be examined within the context of MPA coverage for the purpose of developing a more inclusive country-wide conservation strategy that will insure sport fish habitats are not ruined by inadequate protection from unmanaged development or extraction, but rather are themselves managed as critical economic and biological resources for posterity, much in the same way as Belize's marine protected areas currently undertake to manage the Belize Barrier Reef.

Overview

The research design employed for determination of development-born threats to the three target sport fish species entailed collation of 25 thematic map scenes spanning the entire country of Belize into a GIS project, followed by interviews with more than a dozen fishers to learn and mark where each of the 3 sport fish species were being captured, where they were known or thought to occur during various stages in their life history, or from where they were thought to have been extirpated. The acquired information was then plotted as a new theme in GIS for each species of sport fish and added to the GIS project.

Map Works

Satellite data were acquired from the USGS LandSat-7 platform at 30 meters resolution; and the Google/Quickbird platform at 14.25 meters resolution by Ecoworks. All data sets were projected in UTM with WGS84 datum. Two types of band sets were used, which include RGB bands 321 from the Landsat-7 platform, and bands 421 (4 being the infrared band for enhanced chlorophyll separation) from the Quickbird platform. These scenes were sharpened, their respective histograms matched, and then mosaiced using Envi 4.2 to speed GIS project loading. LandSat-7 pan bands having 10 meters resolution were also sharpened and stretched with standardized blue/white Envi 4.2 colorization tables for fine resolution of small areas.

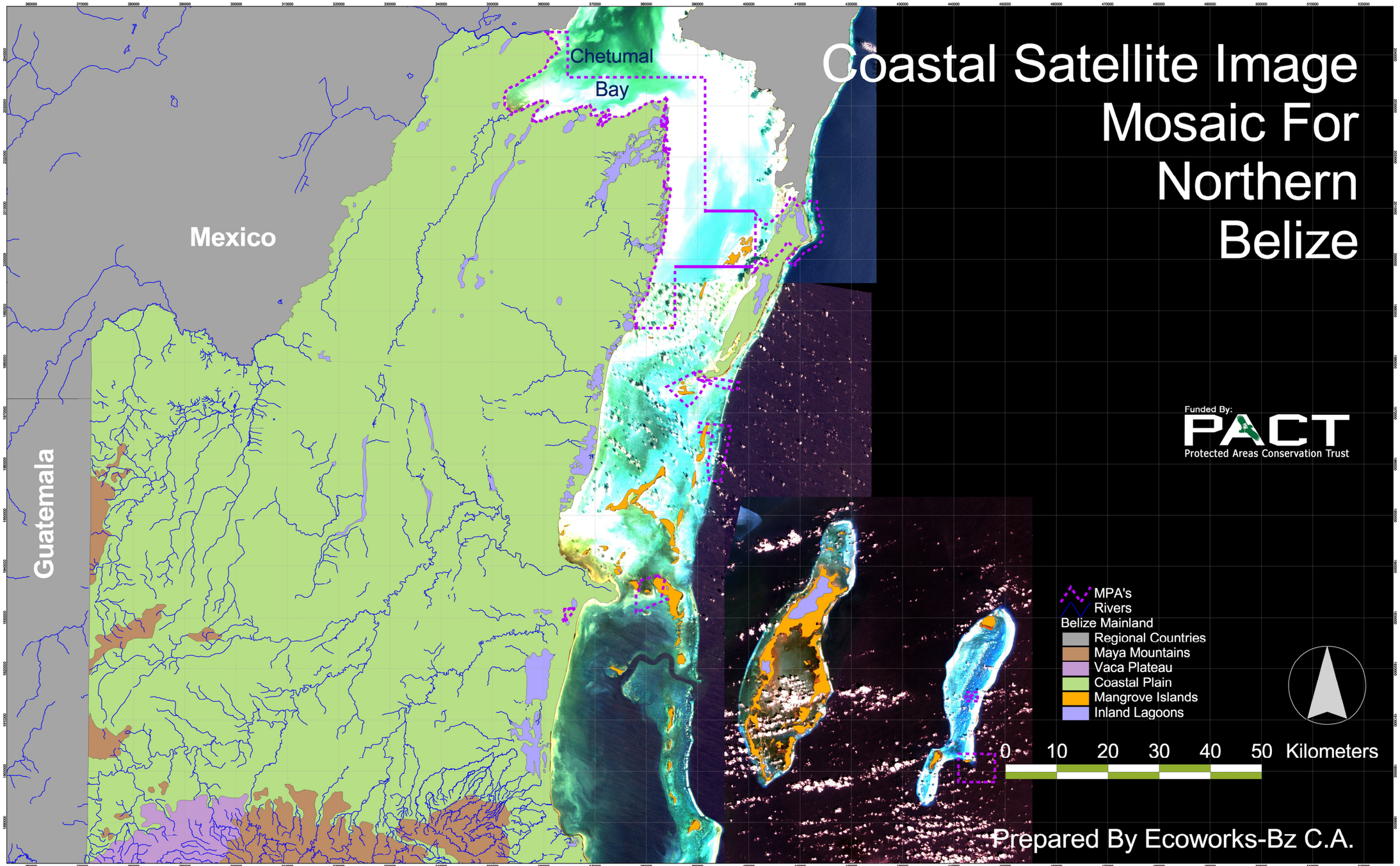
Bathymetric maps were registered in GIS from British Admiralty Navigation Charts published by the US Defense Department following World War II. Paper maps were digitally scanned, and then re-mosaiced in Adobe Photoshop CS4 before being rubber-fitted into the GIS project using satellite data as the geo-referencing standard by Ecoworks. Marine habitat spatial extents originally mapped by Mumby *et al* (1998) were imported into the GIS project as 15 discrete thematic layers which were subsequently eye fitted to satellite data as the geo-referencing standard by Ecoworks. Mapping error was deemed to be $\pm$ 30 meters following the USGS recommendation for local spatial geo-referencing error associated with LandSat-7 algorithms.

Interviews

Green Reef conducted interviews with more than twenty fisher-folks from the tour-guide and artisanal fishing industries during the month of March. Interviews were elected over formalized questionnaires for stakeholder input owing to the greater amount of information retrieval associated with the former methodology. Many additional fisher folk were contacted for interview, but scheduling could not be consolidated, so the decision was taken to update findings as necessary during workshop presentations schedule for the 3rd phase of works.

Compilation & Analysis

Life history narratives along with geo-spatial conservation recommendations for each of the three target species were developed by using published life history information as a framework on which to fit local fisher insights and reported species distributions in Belize. These findings are presented as the study's results along with the relevant map works for each of the 3 sport fish species examined.


Coastal Satellite Image Mosaic For Northern Belize
Chetumal Bay
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PACT
Protected Areas Conservation Trust
MPA's
Rivers
Belize Mainland
Regional Countries
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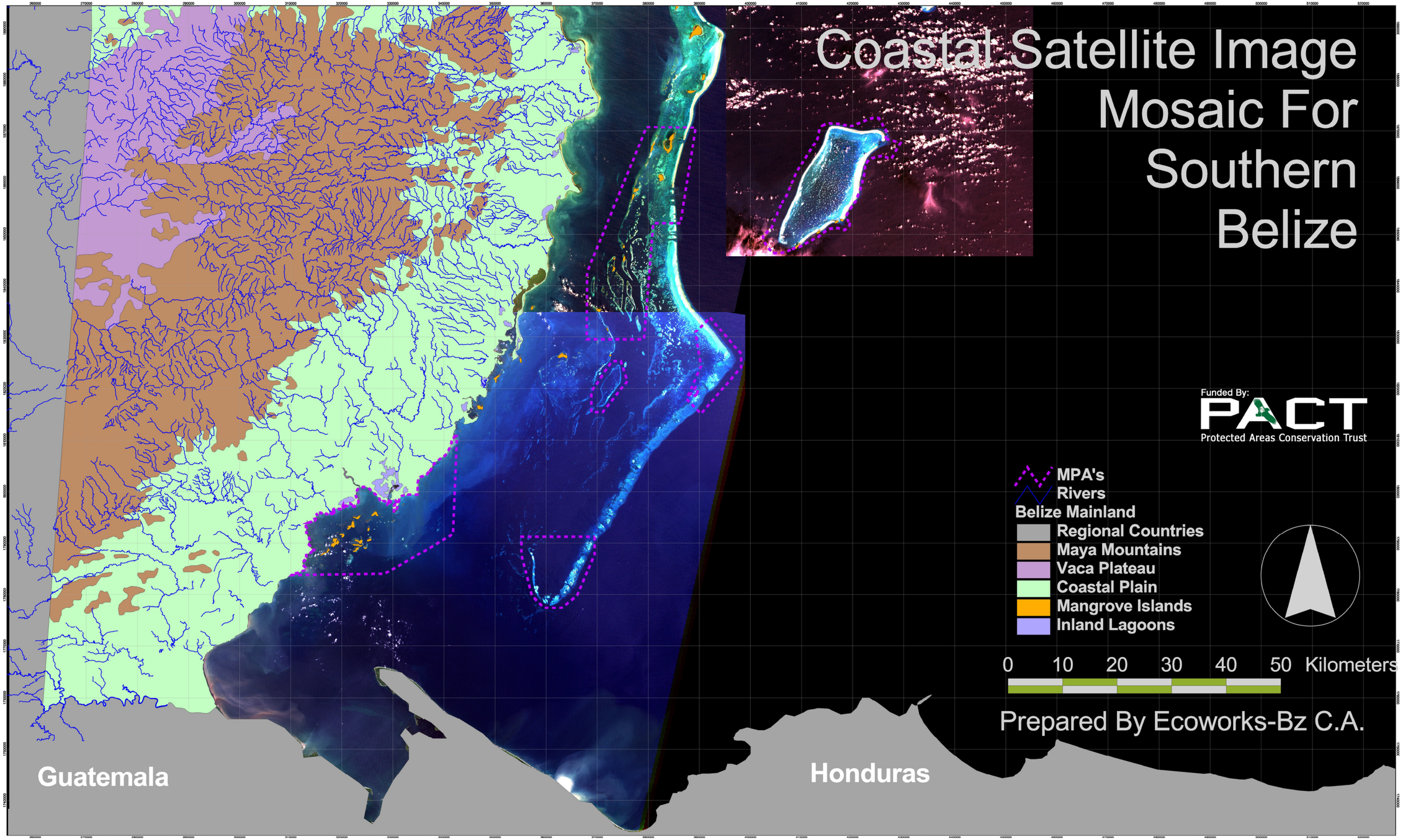
Coastal Satellite Image Mosaic For Southern Belize
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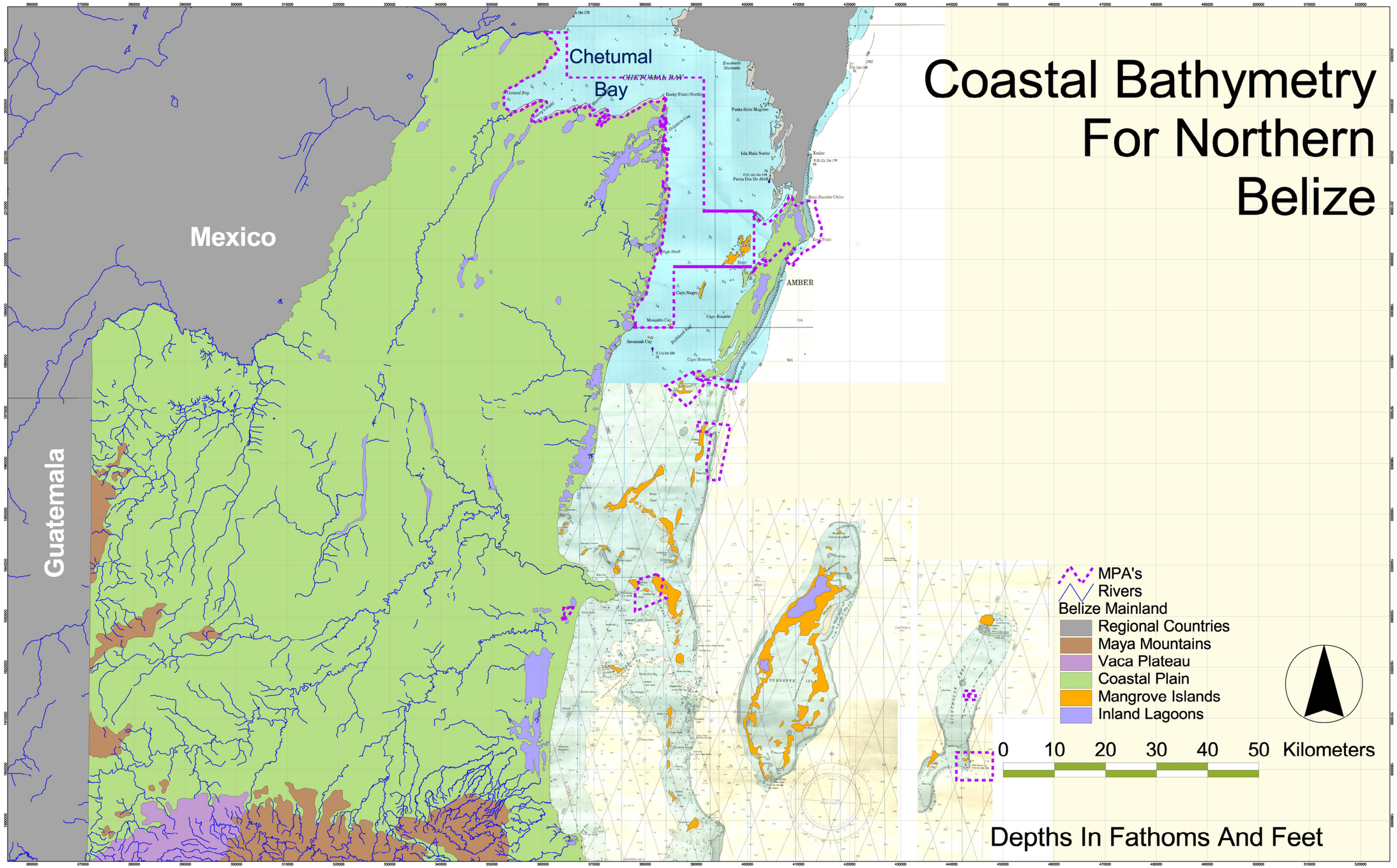
Coastal Bathymetry For Northern Belize
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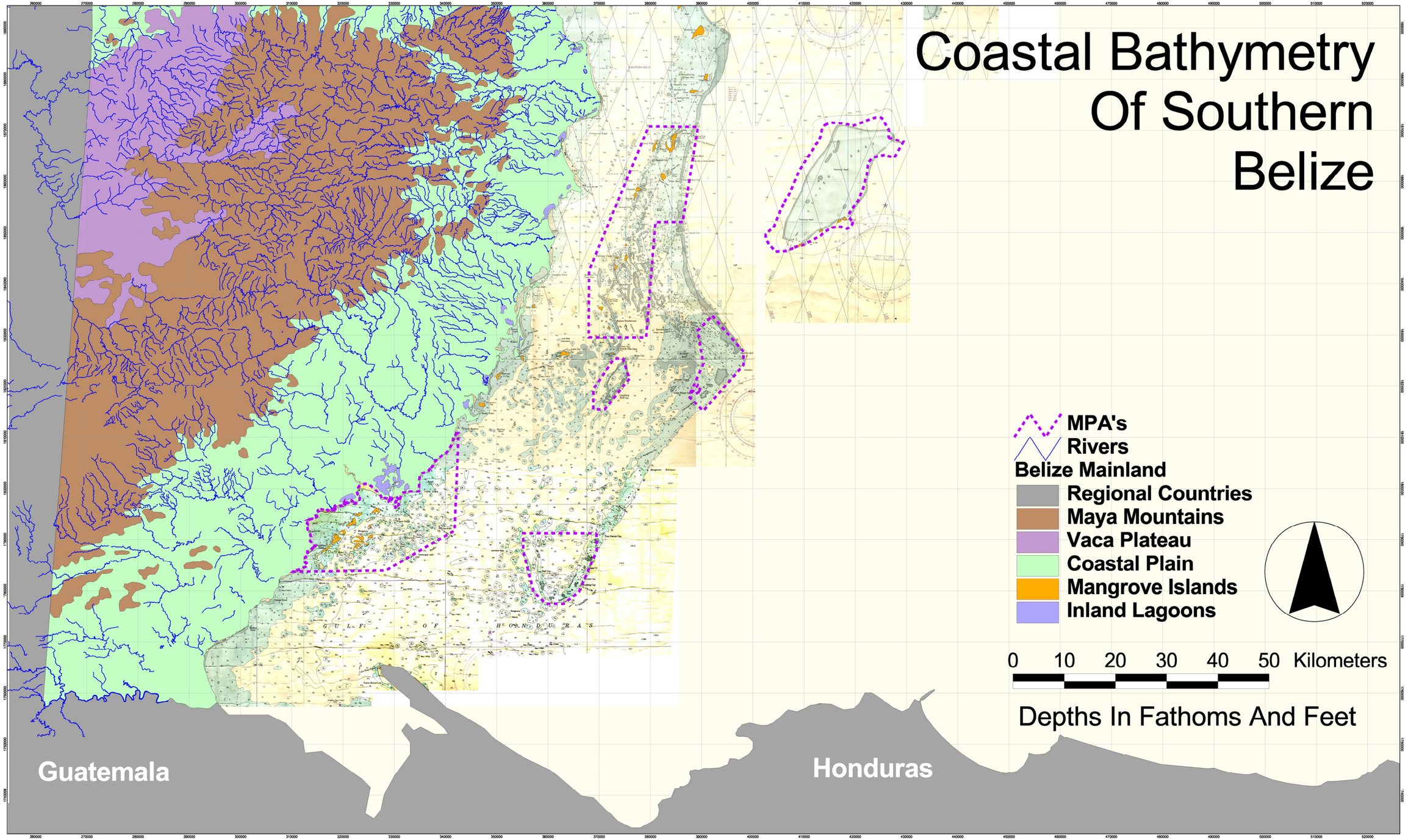
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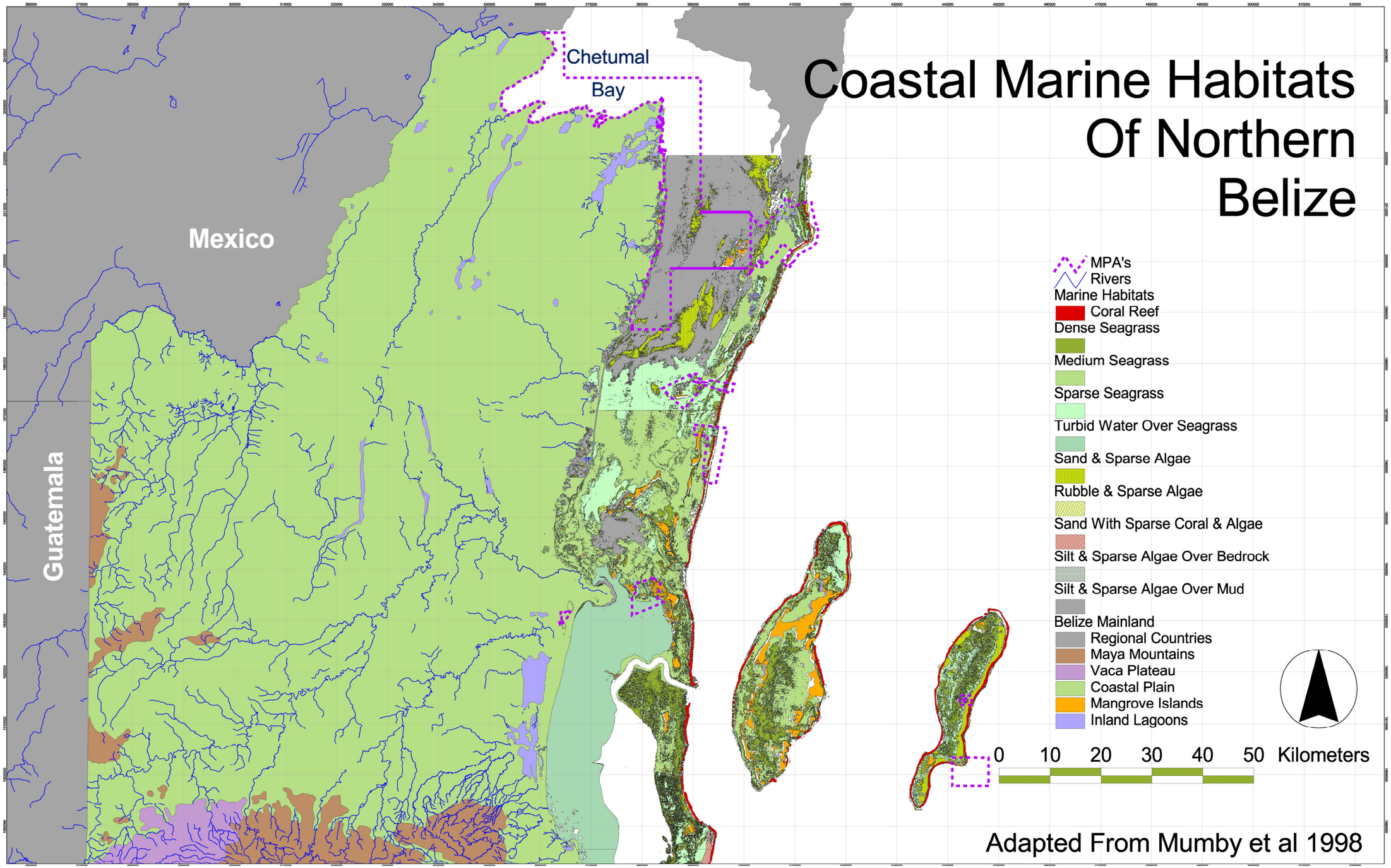
Depths In Fathoms And Feet
Guatemala
Honduras
GULF OF HONDURAS


Coastal Marine Habitats Of Northern Belize
Chetumal Bay
Mexico
Guatemala
MPA's
Rivers
Marine Habitats
Coral Reef
Dense Seagrass
Medium Seagrass
Sparse Seagrass
Turbid Water Over Seagrass
Sand & Sparse Algae
Rubble & Sparse Algae
Sand With Sparse Coral & Algae
Silt & Sparse Algae Over Bedrock
Silt & Sparse Algae Over Mud
Belize Mainland
Regional Countries
Maya Mountains
Vaca Plateau
Coastal Plain
Mangrove Islands
Inland Lagoons
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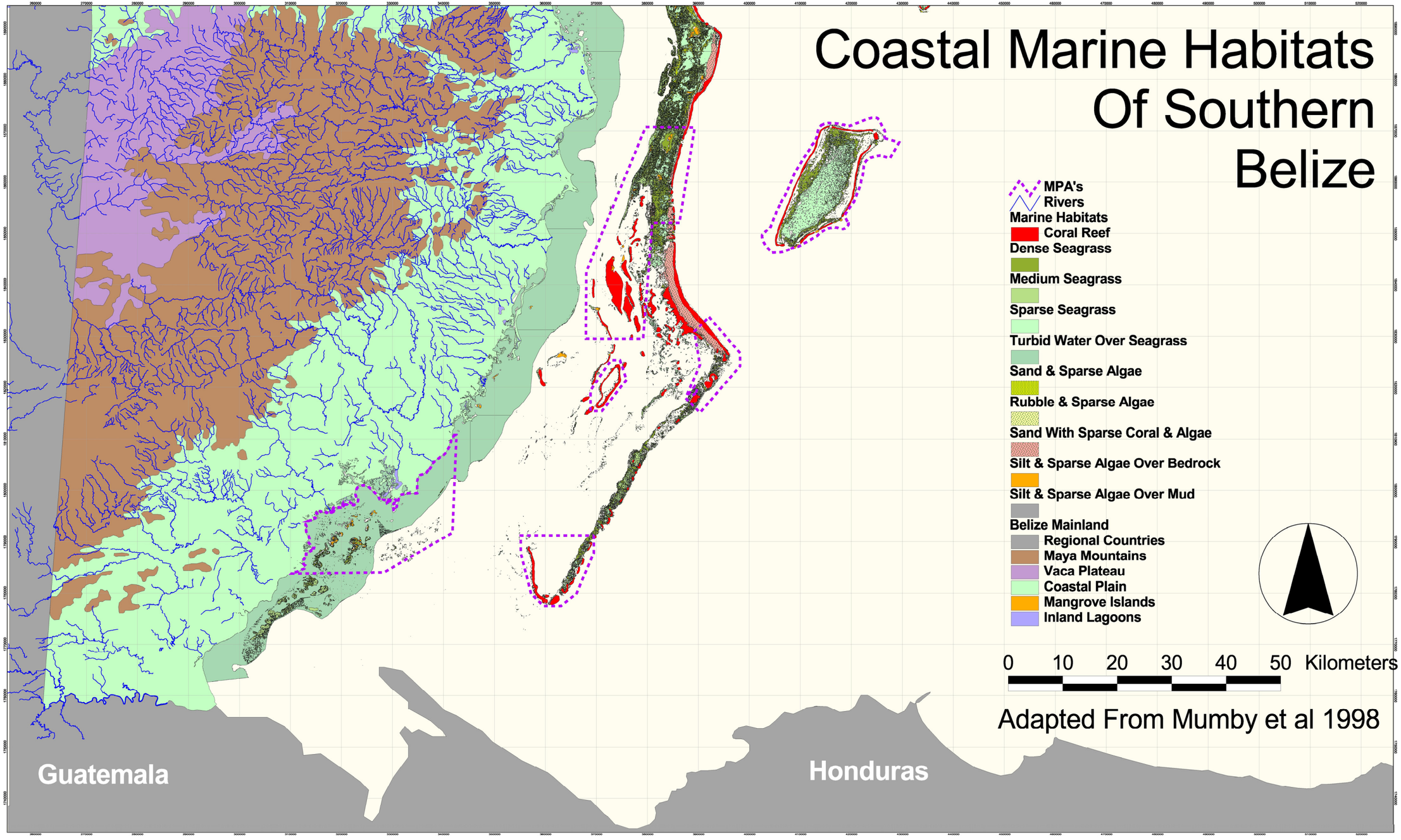
Adapted From Mumby et al 1998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0 10 20 30 40 50 Kilometers
Adapted From Mumby et al 1998
Guatemala
Honduras

Formal Nomenclature:

Kingdom:	Animalia -- animal,
Phylum:	Chordata -- chordates,
Subphylum:	Vertebrata -- vertebrates
Superclass:	Osteichthyes -- bony fishes,
Class:	Actinopterygii -- ray-finned fishes, spiny rayed fishes
Subclass:	Neopterygii -- neopterygians
Infraclass:	Teleostei
Superorder	Elopomorpha
Order	Albuliformes
Suborder	Albuloidei
Family	Albulidae -- bananafishes, bonefishes, ladyfishes, macabíes
Subfamily	Albulinae
Genus	*Albula*, Scopoli, 1777 -- bonefishes
Species	*Albula vulpes* (Linnaeus, 1758) -- bonefish, macabí

(Source: Integrated Taxonomic Information System: www.itis.gov)

Common Names:

Commonly, bonefish are named for the many fine bones they contain. English common names include banana, banana fish, Indo-Pacific bonefish, ladyfish, round jaw, salmon peel, tarpon, tenny, and tenpounder. Other common names include carajo (Spanish), chache (Swahili), colepinha malabu (Creole), colvino (Spanish), conejo (Spanish), gatico (Spanish), gato (Spanish), inliaula (Spanish), liguija (Spanish), macabi (Spanish), macabi del helbra (Spanish), macabie (Spanish), macaco (Spanish), parra (Spanish), peje gato (Spanish), raton (Spanish), raton de mar (Spanish), sanducha (Spanish),), ten-pounda (Creole), and zorro (Spanish). (Source: Florida Museum of Natural History Ichthyology Department; www.flmnh.ufl.edu)

Physical Description

One of the most distinctive characteristics of the bonefish is the inferior mouth and conical nose that protrudes a third of its length beyond the mandible. The body is slender, round, and compressed, more so in large specimens than in young adults. The dorsal profile is more convex than the ventral profile. The first few rays of the dorsal fin are higher than the following rays and this lends a somewhat triangular shape to the dorsal fin when erect. The caudal fin is deeply forked, with the upper lobe slightly larger than the lower. Bonefish appear blue-greenish above, with bright silver scales on the sides and below. Dark streaks run in between the rows of scales, predominantly on the dorsal side of the body. The dorsal and caudal fins have dusky margins. Bonefish have no spines. Juvenile bonefish exhibit a series of nine dark crossbands on their backs. These bands extend nearly to the lateral line, with the third band crossing at the origin of the dorsal fin. Bands four and five are found under the posterior base of the dorsal fin. As the juvenile bonefish age the bands begin to disappear with the posterior bands the first to fade. Beyond about 3 inches (7.5 cm) the dark longitudinal streaks characteristic of the adults begin to appear and the last of the crossbands become obscured. (Source: Florida Museum of Natural History Ichthyology Department; www.flmnh.ufl.edu)

There are three species of Bonefish in the Caribbean, *Albula vulpes* (the common Bonefish in Belize); *Albula garcia* (Bigeye Bonefish) discovered in 2001, which ranges from the Bahamas to Mexico and Belize; and *Albula sp* discovered in 2008. The three species are only distinguishable by genetic testing. *Albula vulpes* has no dorsal spines; 15 - 19 soft dorsal rays; no anal spines; 7 - 9 soft anal rays; 69 - 74 vertebrae; and 12 - 14 branchiostegal rays. (Source: Fishbase).

Global Distribution

Bonefish inhabit tropical and warm temperate waters worldwide, Although western Atlantic bonefish are occasionally taken as far north as North Carolina, New York, and New Brunswick, this species is most plentiful in south Florida, the Bahamas, and Bermuda. To the south, they range throughout the Caribbean Sea to Brazil. On the eastern Pacific coast, the bonefish occurs from San Francisco Bay, California, south to Peru and west to Hawaii.

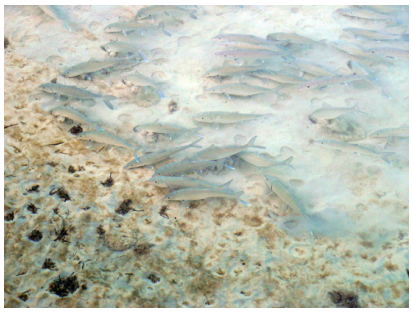
World-Wide Distribution Of Bonefish

Life History & Habitat Interactions

Bonefish begin life as leptocephalus larvae spawned during annual breeding aggregations in the Caribbean Sea. Male Bonefish mature at an average of 3.6 years of age and 17.4 inches, while female Bonefish reach maturity at about 4.2 years and 18.8 inches. Bonefish, as well as the other two species, spawn by a method known as broadcast spawning where fish gather in groups and release their gametes for fertilization in the open sea. Egg production can range from 0.4 - 1.7 million eggs per female. Population resilience, as measured by doubling time, is moderate at 1.4 to 4.4 years (Source, Fishbase). It is likely that Bonefish commence with egg development in early December and participate in spawning aggregations that peak during new and full moons in March and April each year. Although the exact location of aggregations are presently unknown, they probably occur within a few miles of the Belize Barrier Reef in deep oceanic water and are relatively short-lived events given their negative buoyancy and results from limited tagging studies.

After fertilization, the eggs hatch in less than a day, and then the newly hatched larvae are on their own in the open ocean. The transformation from the transparent, ribbon-like leptocephalus larvae to juvenile bonefish occurs in three distinct stages and takes from 41 to 71 days. Early stage 1 leptocephali lack dorsal, anal, and pectoral fins and are small, usually less than about 30mm. Late in stage 1 the nascent dorsal and anal fins appear and the larvae approaches its maximum size of approximately 63mm. At this length the larvae begins a rapid metamorphosis in which the entire body shrinks for 10-12 days until it reaches half its original length. During this transformation (stage II) the anal and dorsal fins move forward and the snout projects noticeably beyond the mandible. The subsequent appearance of scales, the lateral line, and the onset of an overall appearance of that of a miniature bonefish mark the transformation to a fry (stage III). Pigmentation and crossbands appear at about 4 cm in length, followed by the appearance of longitudinal stripes and the disappearance of the crossbands. At the conclusion of larval stage III metamorphosis, Stage III Bonefish larvae are larger than their Tarpon counterparts, and otherwise differ in recruiting to shallow, sandy beach flats, eventually moving to locations where the flats are bordered by sea grass and/or mangroves.

Leptocephalus Larvae (left), **Juvenile Bonefish School** (center) **and Adult Bonefish** (right)



Stage I larvae are reputed to absorb nutrients directly from seawater. Stage II and III larvae and small juveniles consume small benthic invertebrates common to sand flats, which primarily include mollusks in waters less than 30 cm (12 inches) in depth. The bonefish uses its conical snout to dig through the benthos to root up its prey, which it crushes and grinds with its powerful pharyngeal teeth. Adult Bonefish will expand their diet to include crabs, shrimp and small fish. Like Tarpon, the swim bladder of the Bonefish has an open connection with the gullet and is modified for breathing air, despite its preferred habitat appearing to be clean, shallow, well-oxygenated water.

Important habitats for Belizean Bonefish are the sand flats along the coast and around cayes. In northern Belize, Bonefish were originally found throughout Chetumal Bay, but are now found around the coastal sand flats on the eastern side of Ambergris Caye, the Cayo Francis and San Pedro lagoons, the coastal mainland from Midwinter's Lagoon to the Belize River, and around the Hicks and Riders Cayes. In southern Belize and the outer Atolls, Bonefish appear to be restricted to the sand flats around small cayes and the windward side of Blackbird Caye. Many Bonefish fall victim to gill-netting in the north. The sand flat habitat itself is also under considerable pressure from dredging for tourism development land fills, which together with gill netting, creates a formidable source of mortality for both juvenile and adult Bonefish in Belize.

Species Distribution, Threat Assessment & Recommendations

Consideration of the National Bonefish Distribution Map presented on the following page indicates relatively low Bonefish abundance south of Belize City, at least as compared with northern Belize and similar distributions shown for Tarpon and Permit on the preceding pages. The reasons for such disparity in Bonefish distribution in Belize may be a result of any number of circumstances or combination thereof, including, but not necessarily limited to: (1) insufficient number of interviews with southern fisher-folk; (2) low preferred habitat abundance; (3) competition with Permit and/or other species; (4) poor stage III larval supply to sandy beach recruitment sites; and/or (5) development born damage to recruitment sites.

Juvenile and adult Bonefish appear to take up residence near to their recruitment sites; and they prefer clean shallow water sand flats that are adjacent to shorelines, dense sea grass meadows and mangroves, the latter two probably serving both as feeding and predator avoidance sites. Shallow waters probably also serve in fish predator avoidance, as low angle visibility would be likely to reduce strike effectiveness. Given these considerations, and the distribution of Bonefish in Belize presented herein, it is clear that northern Belize probably offers more total shoreline area for recruitment (e.g. as presented by Ambergris and the Hicks Caye ranges) than southern Belize, which is primarily populated by a few small round sand cayes offering limited recruitment area. Consequently the disparity in bonefish abundance in northern vs. southern Belize may well be a simple consequence of the contiguous *length* of a given recruitment site, more than any other single factor, simply because longer recruitment sites will be easier to recruit to, than a small island that can be easily missed by drifting larvae. This also appears to hold true for the Belizean atolls as well, wherein the Turneffe Islands affords the longest presentation of sandy windward shoreline found outside the Belize Barrier Reef, and also supports the greatest abundance of Bonefishing sites.

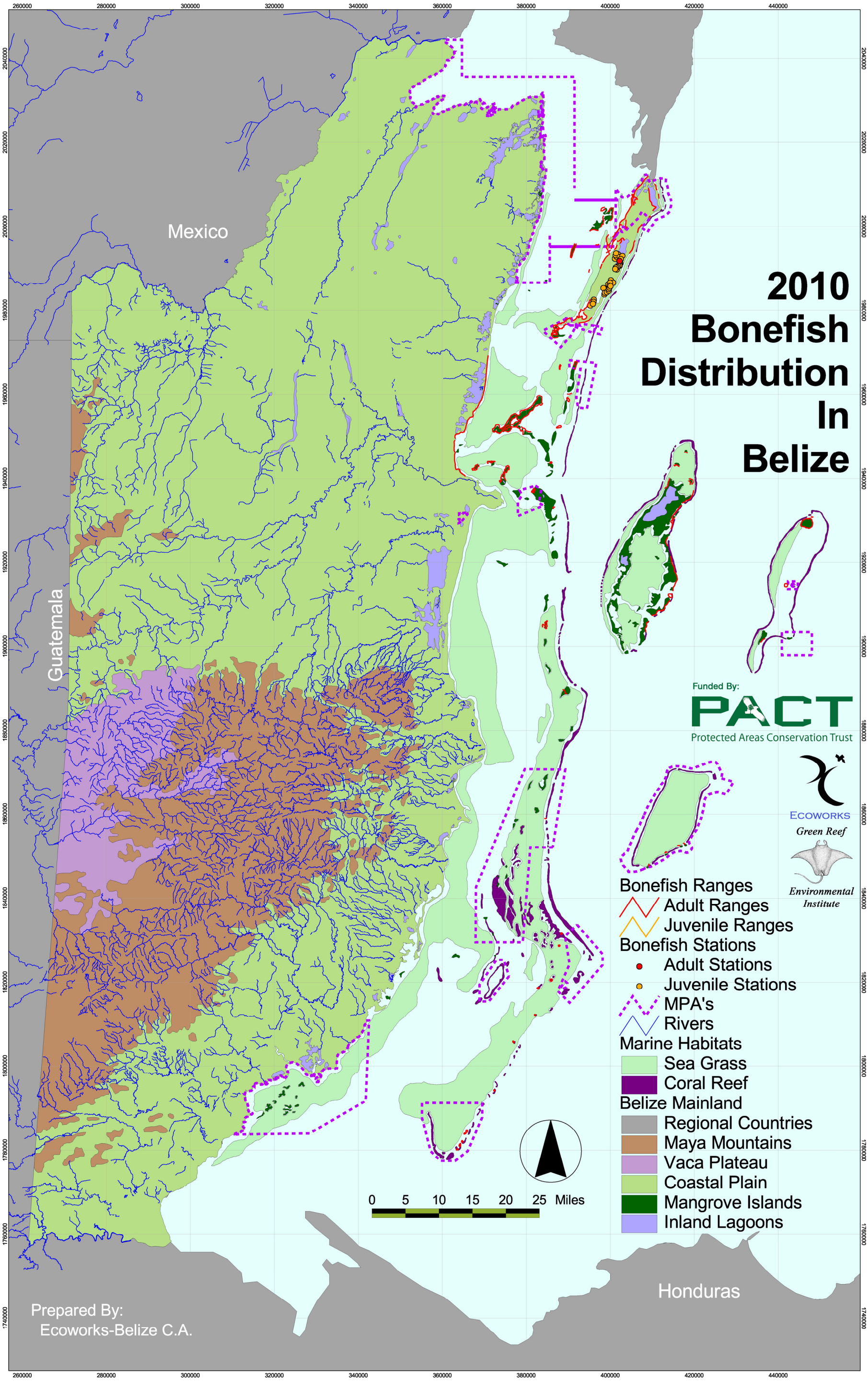
These considerations point to how natural processes and development-based mortality risks can impart their impact on Bonefish populations in Belize. In the former case, sand replenishment along Ambergris Caye is thought to be a result of erosion and transport of the Yucatan shoreline; which is driven by prevailing currents and the regions powerful hurricanes. During senesce of such events, shoreline replenishment rates are reduced, and recruitment site abundance declines.

Dredging operations in support of beach replenishment following hurricanes and/or land fill for development serve to further reduce recruitment site abundance, which in turn can effectively undermine Bonefish stock replenishment from the very onset. It follows then that smaller recruitment sites around Belize's southern cayes and outer atolls are likely to be even more severely impacted by dredging practices for development. Gill netting can only serve to exacerbate such impacts by increasing mortality risks on young of the year juveniles and adults, which are either cut for bait or simply thrown aside because of their low food value.

As with Permit, protected area coverage addresses about half of the Bonefish sites identified by this study, leaving recruitment sites along the windward side of the Ambergris, Hicks, Riders and Drowned Caye ranges; and the Turneffe Islands, and adult sites in these same areas without any formal regulatory coverage whatsoever, beyond the forthcoming sport fishing regulations.

From the foregoing findings, it is clear that priority conservation measures should entail: (1) the prohibition of dredging of windward shorelines for beach reclamation or land fill; (2) the prohibition of gill netting in the vicinity of sand flats adjoining sea grass meadows and/or mangroves. Critical areas being the Cayo Frances and San Pedro Lagoons; the Hicks, Riders and Drowned Caye Ranges; and the shoreline and flats adjacent to Tarpon Cove, Buttonwood Bay and the Belize River; and (3) The development and enforcement of policies and legislative amendments concerning sea grass and wetland habitat reduction that will strategically improve conservation of the mangrove habitat on which juvenile Bonefish depend.

Additionally it is important to note that the deep water spawning behavior and the lengthy larval development time for Bonefish, suggests that at least a portion of the leptocephalus larvae recruiting to the Belize population may well have been spawned along the eastern coast of Yucatan Mexico, while a portion of the leptocephalus larvae spawned in Belizean waters may be recruiting to southern populations in Guatemala, Honduras, Nicaragua, Costa Rica and/or Panama, depending on prevailing current patterns each year; which in turn points to the likely need for bonefish stocks to be managed at the regional level to maximize effectiveness.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Sea Grass
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Maya Mountains
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Coastal Plain
Mangrove Islands
Inland Lagoons
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Prepared By:
Ecoworks-Belize C.A.

Formal Nomenclature:

Kingdom:	Animalia -- animal,
Phylum:	Chordata -- chordates,
Subphylum:	Vertebrata -- vertebrates
Superclass:	Osteichthyes -- bony fishes,
Class:	Actinopterygii -- ray-finned fishes, spiny rayed fishes
Subclass:	Neopterygii -- neopterygians
Infraclass:	Teleostei
Superorder	Acanthopterygii
Order	Perciformes -- perch-like fishes
Suborder	Percoidei
Family	Carangidae -- carangues, jacks, jureles y pámpanos, pampanos, pompanos, saurels
Genus	Trachinotus Lacepède, 1801 -- pompanos
Species	*Trachinotus falcatus* (Linnaeus, 1758) -- pámpano, pámpano palometa, permit

(source: Integrated Taxonomic Information System: www.itis.gov)

Common Names:

Autiranon (Palicur), blå taggmakrell (Norwegian), blå taggmakrill (Swedish), carangue á plumes (French), carangue plume (French), cobbler (English), fausse karang (Creole, French), palometa (Spanish), pampanillo (Spanish), pampanito (Spanish), pampano (Tagalog), pámpano (Spanish), pámpano de bandera (Spanish), pampano erizero (Spanish), pampano palometa (Spanish), pámpano palometa (Spanish), permit fish (English), pompaneau plume (French), round pompano (English), sereia-de-pluma (Portuguese), sernambiguara (Portuguese), sernambiquara (Portuguese), sierpnik okragly (Polish), sinipompano (Finnish). (Source: Florida Museum of Natural History Ichthyology Department; www.flmnh.ufl.edu)

Physical Description

The deeply forked tail and elongated anterior dorsal fin provide the more distinct characteristics of the permit. Looking like long sickles, these fins impart the fish's species name falcatus. However, one can also identify the permit by its highly laterally compressed body, making the fish appear tall and thin. From a lateral perspective, the permit shape looks round in juveniles, but becomes oblong as the fish ages into an adult. In addition to the long anterior dorsal fin, inserted directly above an elongated anterior anal fin, Permit also possess 17-21 soft dorsal rays, and 16-19 soft anal rays. (Source: Florida Museum of Natural History Ichthyology Department; www.flmnh.ufl.edu)

Global Distribution

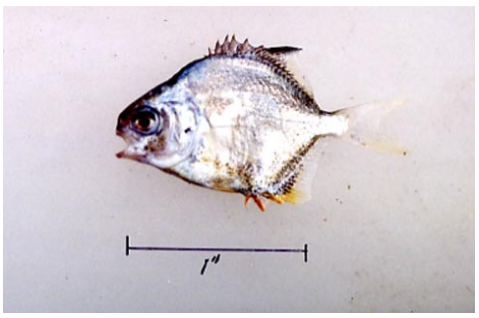
Permit inhabit the western Atlantic from Massachusetts to southeastern Brazil (see Illustration at right). They occur throughout the West Indies and the Gulf of Mexico, and less-frequently in Bermuda. The species has been reported in the eastern Atlantic, but does not regularly occur there. Permit is most abundant in southern Florida.

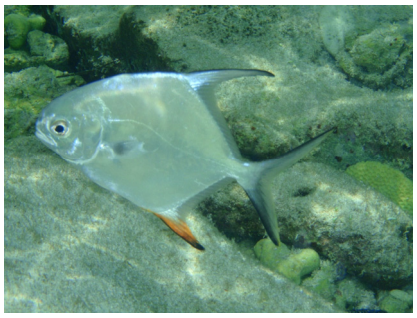
World-Wide Distribution Of Permit

Life History & Habitat Interactions

Permit begin life as larvae that are spawned, in Belize, every month from February through October during full moons at deep water reef promontories. Permit eggs hatch within a day of fertilization, and the newly hatched larvae live as plankton for 15 to 18 days in the open ocean before recruiting to shallow sandy windward beaches where they transform into miniature versions of adult permit; the larval stage resembling adult fish save for differences in size, coloration and fin development.

Larval (left & center) **And Juvenile Permit** (right)



Juvenile permit (15-44 mm in length) initially feed on plankton, including small crustaceans, larval amphipods, and adult insects. Permit between 50 and 110 mm feed on larger crustaceans and mollusks, and those between 110-138 mm primarily eat mollusks, using their hard mouth to dig into the sea floor and pull up prey; and their distinctive plates at the back of the mouth that help to crush hard-shelled crustaceans and mollusks. Adult Permit eat mostly shrimp, crabs, bivalves, fishes and mussels (Finucane, 1969).

Female Permit become sexually mature at about 3 years or about 21 inches, but males mature at smaller sizes than the females at 19 inches and around 2 years of age. Permits are known to live to be at least 23 years. Permit may reach a maximum length of at least 48 inches and a weight of 79 pounds. Permits grow rapidly during the first 5 years of life after which their growth slows considerably.

Permit fecundity is unknown. Similar species such as the Pompano (*Trachinotus carolinus*) are reputed to have notoriously low fecundity. Despite Permit's unknown fecundity however, their longevity; relatively short larval recruitment period, simple life history, and early maturation (unlike Tarpon) imply a moderate population resilience or doubling time of 1.4 - 4.4 years (Fishbase), thereby ameliorating their sensitivity to environmental perturbation.

In Belize, important habitats for permit include sandy beach flats (for recruitment), and open sand flats throughout the Belize Barrier Reef Lagoon, particularly in the central reaches of the Belize Barrier Reef Lagoon, and the Turneffe Islands. Known spawning locations include promontories within the Bacalar Chico Marine Reserve, the southern end of both Turneffe and Light House Atolls, and Gladden Spit.

Detailed Rendering of a Permit (left)**, Adult Permits caught and released in Belize** (center & right)



Species Distribution, Threat Assessment & Recommendations

The National Permit Distribution Map for Belize developed by this study and presented on the following page indicates that juvenile and adult Permit occur throughout Belizean waters wherever their preferred habitats are represented. The sandy beaches of eastern Ambergris, Hicks and Riders Caye ranges; the windward beaches of Turneffe Islands; and those of the Barrier Reef Lagoon Cayes in Central Belize appear to be the most important recruitment sites for Permit in Belize. This finding suggests Permit do not particularly require large target beaches to recruit to as appears to be the case with Tarpon and Bonefish. Juvenile and adult Permit, on the other hand, appear to enjoy similar sandy shoal habitats, and so demonstrate a relatively ubiquitous distribution across Belize, particularly west of Ambergris Caye, and in the central reaches of the country.

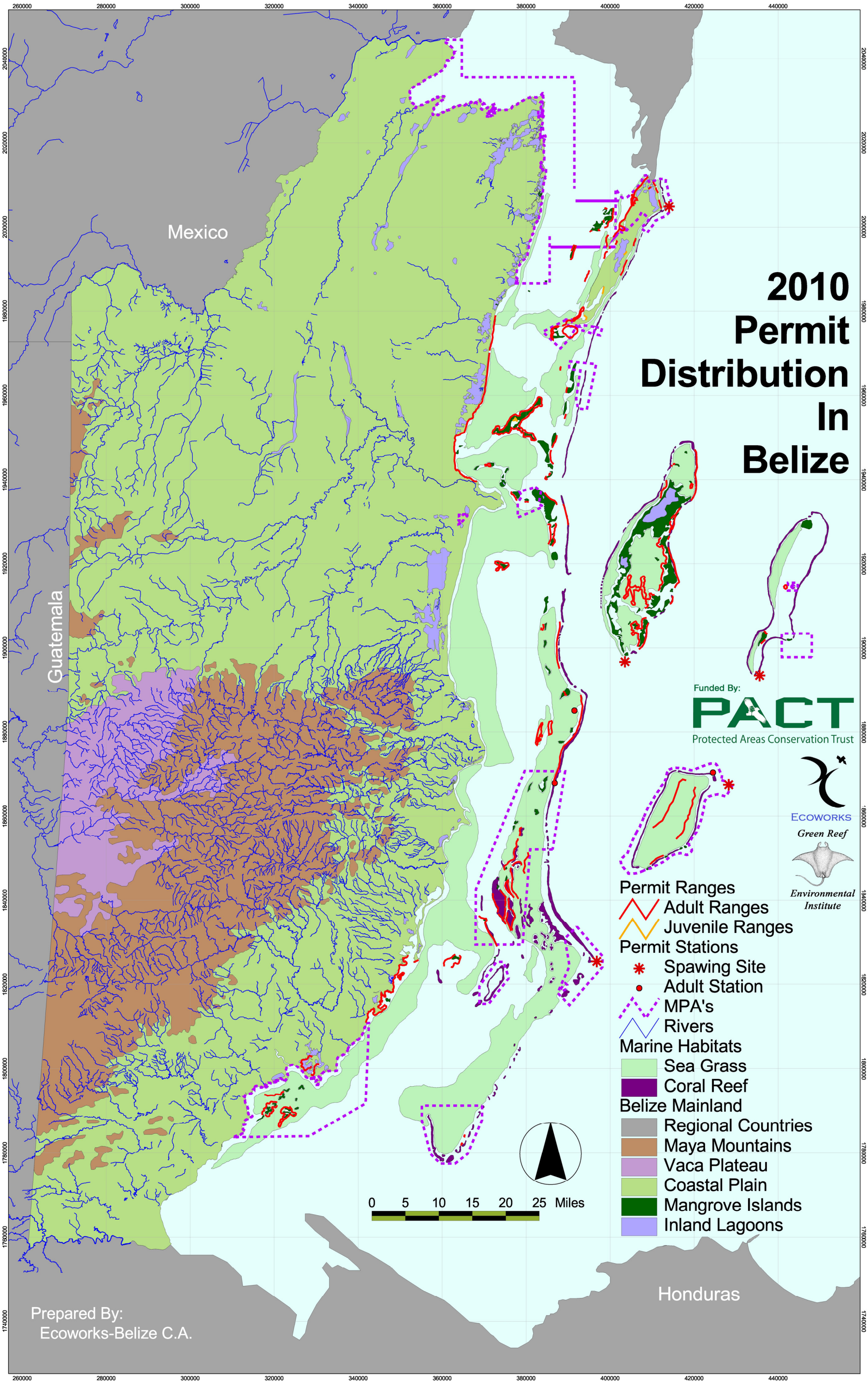
These considerations point to how development-based mortality risks can impart their impact on Permit populations in Belize. Dredging by developers for beach reclamation and landfill can effectively undermine Permit stock replenishment from the very onset through elimination of critical recruitment sites, particularly in central Belize; and it follows then that smaller recruitment sites around Belize's southern cayes and outer atolls are likely to be even more severely impacted by such practices undertaking in support of development. Gill netting and mangrove clearance are lower level threats than with either Tarpon or Bonefish since Permit apparently do not closely associate river mouths or mangrove covered shorelines. However, fishermen capture Permit for sale as a food fish which presents a source of stock mortality not found for Tarpon and Bonefish.

As with Tarpon, human interventions such as over-fishing and/or pollution, although not habitat-specific in scope, nevertheless can impose the risk of eliminating Belize's recruitment imprint in the population. Since after-the-fact mitigation would be pointless once the memory of the run has become irretrievable and irreversibly lost forever, it is important that priority conservation measures are implemented in the near, rather than long term.

Protected Area coverage addresses about half of the Permit sites identified by this study, leaving recruitment sites along the windward side of the Ambergris, Hicks, Riders and Drowned Caye ranges; and the Turneffe Islands, and adult sites in these same areas without any formal regulatory coverage whatsoever, beyond the forthcoming sport fishing regulations.

Priority Permit conservation measures for the near term should then entail: (1) development and enforcement of policies that will insure dredging for beach reclamation and land fill is prohibited at windward recruitment sites; (2) that signed receipts be obtained from fishers who illegally sell Permit to grocery outlets and restaurants; and (3) development and dissemination of best practices guidelines for sport fishers to insure catch & release activities do not result in chronic deterioration of adult Permit ability to capture prey and feed effectively.

Additionally it is important to note that the deep water spawning behavior and the 15 - 18 day larval development time for Permit, suggests that at least a portion of their larvae recruiting to the Belize population may well have been spawned elsewhere in Central America or the Caribbean, while a portion of the Permit larvae spawned in Belizean waters may also be recruiting elsewhere in the region, depending on prevailing current patterns each year, which in turn points to the likely need for Permit stocks to be managed at the regional level to maximize effectiveness.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2010 Permit Distribution In Belize
Funded By:
PACT
Protected Areas Conservation Trust
ECOWORKS
Green Reef
Environmental Institute
Permit Ranges
Adult Ranges
Juvenile Ranges
Permit Stations
Spawing Site
Adult Station
MPA's
Rivers
Marine Habitats
Sea Grass
Coral Reef
Belize Mainland
Regional Countries
Maya Mountains
Vaca Plateau
Coastal Plain
Mangrove Islands
Inland Lagoons
0 5 10 15 20 25 Miles
Prepared By:
Ecoworks-Belize C.A.

Formal Nomenclature:

Kingdom:	Animalia -- animal,
Phylum:	Chordata -- chordates,
Subphylum:	Vertebrata -- vertebrates
Superclass:	Osteichthyes -- bony fishes,
Class:	Actinopterygii -- ray-finned fishes, spiny rayed fishes
Subclass:	Neopterygii -- neopterygians
Infraclass:	Teleostei
Superorder:	Elopomorpha
Order	Elopiformes -- Tarpons
Family	Megalopidae -- Tarpons (sábalos)
Genus	*Megalops* -- Lacepède, 1803
Species:	*Megalops atlanticus* -- Valenciennes in Cuvier and Valenciennes, 1847

(Source: Integrated Taxonomic Information System: www.itis.gov)

Common Names:

Abalitsa, Atlantic Tarpon, Atlantischer Tarpun, Bass, Big Scale, Caffum, Camurupi, Grande Ecaille, Grand-Écaille, Grande Ecoy, Jewfish, Madzorfloe, Manyofle, Mell, Ofin, Palika, Peixe-Prata, Peixe-Prata-Do-Atlântico, Pez Lagarto, Sabalo, Sábalo (In Belize), Sabaloreal, Sabilo Real, Sadina, Savalle, Savallo, Savaloreal, Savanilla, Silberfisch, Silverfish, Suwiki, Tainha, Tainha-Congo, Tapam, Tarpao, Tarpão, Tarpão-Do-Atlântico, Tarpoen, Tarpom, Tarpón, Tarpon Argenté, Tarpon Atlantycki, Tarpon (In Belize), Trapoen, Tarpone Tarpone, Tarponi, Tarpum, Trapoen, and Wallidöër. (Source: Florida Museum of Natural History Ichthyology Department; www.flmnh.ufl.edu)

Physical Description

The almost vertical, silvery sides made up of large scales are the most distinctive feature of the tarpon. The tarpon has a superior mouth with the lower mandible extending far beyond the gape. The fins contain no spines, but are all composed of soft rays. The dorsal fin appears high anteriorly and contains 13-15 soft rays with the last ray greatly elongated into a heavy filament. The caudal is deeply forked, and the lobes appear equal in length. The anterior portion of the anal fin is deep and triangular. The fin has 22-25 soft rays, with the last ray again elongated as in the dorsal fin, but shorter and only present in adults. The tarpon has large pelvic fins, and long pectoral fins containing 13-14 soft rays. (Source: Florida Museum of Natural History Ichthyology Department; www.flmnh.ufl.edu)

Global Distribution

Tarpon inhabit a large range on both sides of the Atlantic Ocean (see Illustration at right). The range in the Eastern Atlantic extends from Senegal to the Congo. In the Western Atlantic, the fish primarily inhabit warmer coastal waters concentrating around the Gulf of Mexico, Florida, and the West Indies. However, Tarpon are not uncommon as far north as Cape Hatteras, and the extreme range extends from Nova Scotia in the north, Bermuda, and to Argentina to the south. Tarpon have been found at the Pacific terminus of the Panama Canal and around Coiba Island.

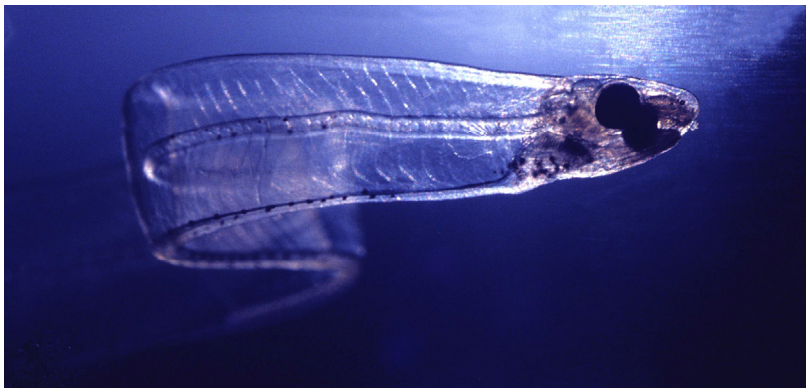
World-Wide Distribution Of Tarpon

Life History & Habitat Interactions

Tarpon begin life as leptocephalus larvae spawned during annual breeding aggregations in the Caribbean Sea. Although spawning by the Belizean population is thought to occur near the new and full moons during late spring and summer every year some 75 miles east of the mainland, the actual location presently remains unknown. Tarpon participate in broadcast spawning and are capable of multiple spawns in a single season. Male and female Tarpon gather in groups in offshore waters and release eggs and sperm into the open water; fertilization is external. Tarpon are extremely prolific. A six foot-eight inch female weighing 142 pounds was observed to contain about 12,000,000 eggs (Böhlke and Chaplin, 1968).

After fertilization, the eggs hatch in less than a day, and then the newly hatched larvae are on their own in the open ocean. The transformation from the transparent, ribbon-like leptocephalus to juvenile tarpon occurs in three distinct stages. Stage 1 leptocephali grow to a length of 6-28 mm and last from 2-3 months. Instead of continuing growth in stage 2, the larvae shrink to about 14 mm. This stage lasts 20-25 days. The larvae grow again in stage 3 and become juveniles at a length of approximately 40 mm, this final stage lasting about 7-8 weeks. Once Tarpon move into wetland habitats they undergo a change in shape, and over the course of a week or so begin to look like miniature adults.

Leptocephalus Larvae (left) **And Juvenile Tarpon** (right)



Stage I larvae are reputed to absorb nutrients directly from seawater. Stage II and III larvae and small juveniles consume copepods, ostracods, zooplankton, insects and small fish. Copepods and small fish constitute over 95% of the total food volume of young Tarpon through the size range of 16 to 75 mm S.L. (Böhlke and Chaplin, 1968). The swim bladder of the Tarpon has an open connection with the gullet and is modified for breathing air, with the result this fish can live in vitiated waters, drawing the fisherman's attention by rolling at the surface periodically to take in air. Juveniles, especially, are found in ponds which are variously described as stagnant, foul-smelling, or of dark water, many of them connected with the sea only at high water. Most of the predators of young Tarpon cannot stand such conditions (Böhlke and Chaplin, 1968).

Important wetland habitats for Belizean Tarpon include most mangroves around cayes, the mangrove fringe along the Cayo Frances and San Pedro Lagoons, most other coastal lagoons, and the mangrove fringe along river mouths, particularly in the south from the Sarstoon to Sibun rivers, and in the north from Salt Creek to the Rio Hondo. Many juvenile Tarpon fall victim to gill-netting in these areas, and therefore never live long enough to contribute to the sport fish population. The mangrove habitat itself is also under considerable pressure from tourism development, both in terms of physical reduction as well as contamination with sewage and domestic pesticide runoffs, which together with gill netting, creates a formidable source of mortality on newly recruiting juvenile Tarpon in Belize.

After a couple of years residence in wetlands, juvenile Tarpon having attained 2 to 3 feet in length will migrate out of the wetlands to coastal flats and estuarine habitats, which in northern Belize have been noted to include the shoals north of Lowery and Warrie Bights in Chetumal Bay, the Bulkhead Shoals west of Ambergris Caye, and elsewhere in Belize, most river and creek mouths. Tarpon can tolerate euryhaline environments (0-47 parts per thousand) and often enter river mouths and bays from which they travel upstream into fresh water. The only physical property that seems to limit their choice of habitat is temperature, and research shows Tarpon to be thermophilic. Rapid decreases in temperature have been known to cause large Tarpon kills. During such temperature drops, Tarpon usually take refuge in warmer deeper waters.

All Tarpon appear to spend at least some time in freshwater, the technical reasons for which appear to be either unasked or unstudied. In Belize, Tarpon tend to migrate up select waterways such as the New River, the Belize River and many others to access inland freshwater lagoons such as the New River, Spanish Creek, and Southern Lagoons, to name only a few. These localized migrations are likely to be exposed to land-based pollution, particularly in the north, which can include runoffs contaminated with heavy metals and/or agricultural pesticides that contaminate flesh and/or kill an those individuals subjected to long term exposure. Sub-adults surviving such exposure and arriving in Belize's freshwater rivers and lagoons are likely to assume the role of an apex predator in the habitat, with little competition save from their own cohorts, and little predation threat, save perhaps from an opportunistic Crocodile (*Crocodylus acutus*) or Bull Shark (*Carcharhinus leucas*). The osmotic shock caused by movement into freshwater may also be benefiting these sub-adult migrants by killing off marine parasites that have colonized their skin and gills during their less mobile residence in wetlands as early juveniles.

Once Belizean Tarpon have achieved 4 to 5 feet in length, they begin to move out of the freshwater lagoons and creeks, into the open waters of the Belize Barrier Reef Lagoon, to eventually take up residence around the Hicks & Rider Caye ranges, and in the tidal cuts through mangrove islands such as the Drowned Caye Range, over back-reef flats, and the many cuts, channels and canyons of the Barrier Reef and its other nearby reefs at Turneffe, Lighthouse and Glovers, where they drift in schools during the day. Large schools may inhabit a specific area on a reef for years where they can be reliably observed (Humann and Deloach, 2002).

Tarpon become sexually mature as they approach 1.4 meters and/or 10 years in age and they are known to live as long as 75 years of age. Tarpon grow rapidly during the first 12 years of life. Female Tarpon generally grow larger and live longer than male Tarpon. Despite their high fecundity and longevity; the long larval recruitment period, complex life history, and late maturation of Tarpon imply a relatively low population resilience or doubling time of 4.5 - 14.0 years (Fishbase), thereby increasing their sensitivity to environmental perturbation. As Tarpon mature, they prey on fish, particularly mid-water prey such as mullets, pinfish, marine catfishes, Atlantic needlefish, sardines, shrimp, and crabs, as well as larger invertebrates including shrimp and crabs. Tarpon feed during both day and night. Because of their small teeth, they usually swallow their prey whole.

Tarpon spend their adult years as members of either a localized or migratory population, with non-migrating Tarpon averaging from 30 to 50 lbs and migratory Tarpon reaching weights over 150 lbs. Migratory or Mega-Tarpon do not appear to be genetically distinct from local populations, but do travel well beyond the range of the local population from which they were likely to have been derived. Whether Tarpon join migratory populations during spawning, or some other time of year is unknown. There are two migratory Tarpon populations which appear to circum-navigate the Gulf of Mexico in opposite directions, one of which continues its migrations as far north as the Carolinas in the US, but less is known about the other population. Huge schools of Tarpon have been observed to form during breeding season just north of

Belize in southern Yucatan, and so Mega-Tarpon which appear in Belize during spawning season may either belong to a third and as yet unrecognized migratory population native to the western Caribbean, or belong to one of the two northern migratory populations. Only further tagging studies will resolve this issue.

Rendering And Photo Of Non-Migratory Tarpon (left & center)**, Mega-Tarpon Captured Off Texas Coast** (right)

In Belize, Mega-Tarpon cross the Barrier Reef at select locations and thereafter follow a dedicated route to equally select feeding grounds within the Barrier Reef Lagoon (BRL) before leaving to rejoin their migratory run. Existing local runs of Mega-Tarpon reported by fisher-folk include individuals entering the BRL through (1) the Basil Jones, Palmeros and Mexico Rocks channels to feed behind the Barrier Reef just offshore from Ambergris Caye; (2) the northern Long Caye channel, where they feed along a course that extends between two shoals just west of the Caye, around Hicks Caye and over to Tarpon Cove as far as Buttonwood Bay and the mouth of the Belize River; (3) cuts in the Barrier Reef between Bluefield Range and Colson Caye where they feed opportunistically along the Barrier Reef platform; and (4) the Tobacco Caye channel where they feed along the back reef flat. At one time Mega-Tarpon entered the BRL through the Hol Chan channel east of Ambergris Caye to feed among the bogues just south of Ambergris Caye, however this run disappeared after Hurricane Keith and appears to have become extinct.

Species Distribution, Threat Assessment & Recommendations

The National Tarpon Distribution Map for Belize developed by this study and presented on the following page indicates that juvenile and adult Tarpon occur throughout Belizean waters wherever their preferred habitats are represented. The mangrove lined lagoons of Ambergris Caye, particularly the San Pedro and Cayo Frances lagoons, appear to be the most important recruitment sites for Tarpon in Belize. This finding probably results from the simple fact that large recruitment sites, such as those found on Ambergris Caye, should be easier for larvae to recruit to; while smaller sites, such as the comparatively tiny cayes of the Belize Barrier Reef, are probably easier for recruiting larvae to miss altogether. Juvenile / adolescent Tarpon, on the other hand, appear to enjoy a ubiquitous distribution across Belize, although they have been almost entirely extirpated from some river mouths by gill netting, particularly in southern Belize.

Adult, *non*-migrating Tarpon are generally represented at a greater number of sites in northern Belize and at Turneffe Islands than elsewhere in Belize, which is a likely result of their being a far greater number of mangrove channel sites found at these two particular locations. Interestingly, these sites do not appear to be competitively occupied by migrating Mega-Tarpon. Rather these adults appear to prefer reef cuts over mangrove channels, their displacement from the mangrove channels of southern Ambergris Caye by hurricane Keith suggesting the reason for this preference may be closely linked to current speed and/or habitat quality.

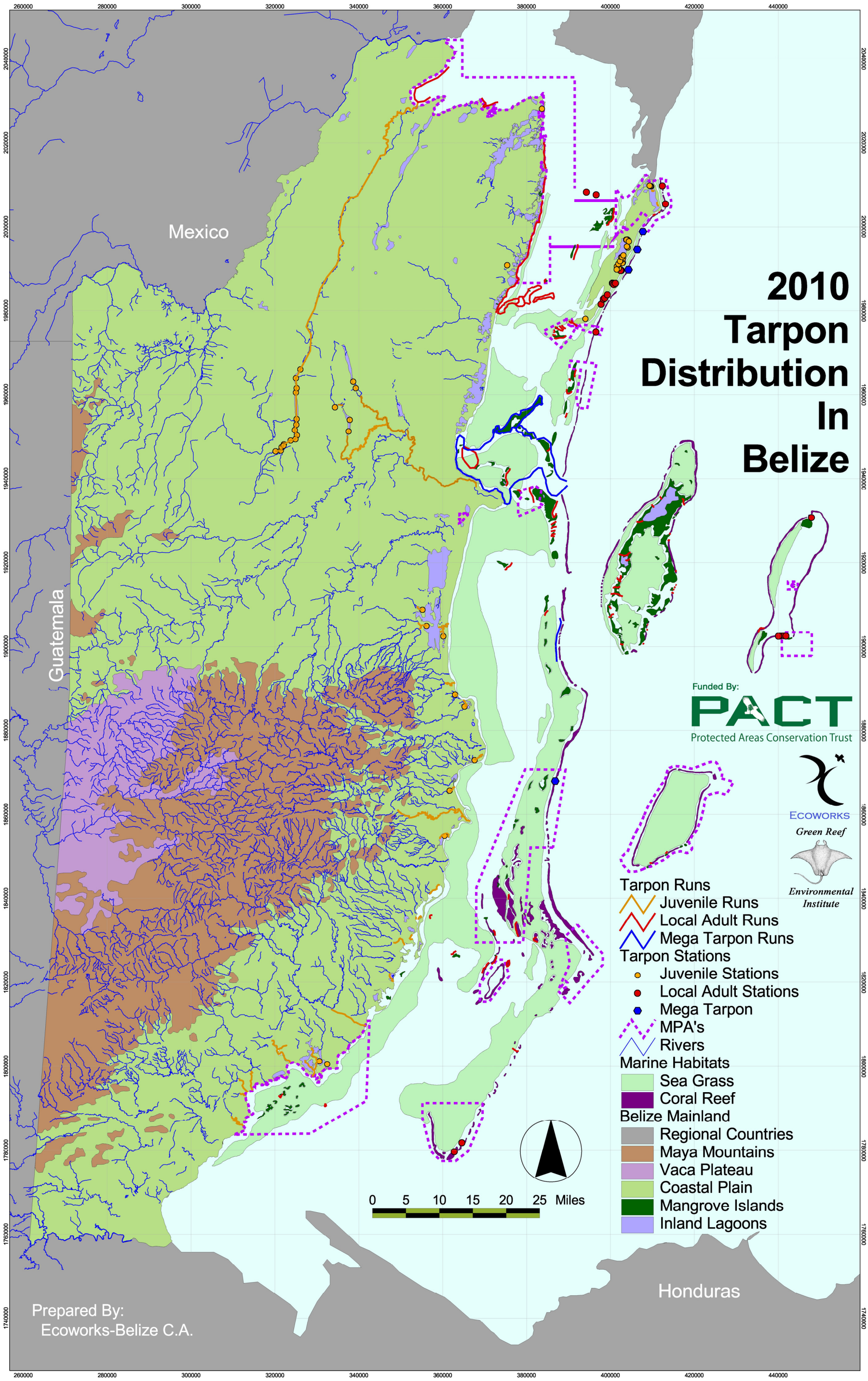
These considerations point to how development-based mortality risks can impart their impact on Tarpon populations in Belize. Mangrove clearing by developers to gain waterfront access to land can effectively undermine Tarpon stock replenishment from the very onset through elimination of critical recruitment sites, particularly on Ambergris Caye; and it follows then that smaller recruitment sites around Belize's southern cayes and outer atolls are likely to be even more severely impacted by such practices undertaken in support of development. Gill netting can only serve to exacerbate such impacts by increasing mortality risks on young of the year juveniles and adults, which are either cut for bait or simply thrown aside because of their low food value.

Human interventions such as over-fishing and/or pollution, although not habitat-specific in scope, nevertheless can impose the risk of eliminating Belize's migratory imprint in the population, as appears to have occurred in the case of the southern Ambergris Caye run. Since after-the-fact mitigation would be pointless once the memory of the run has become irretrievable and irreversibly lost forever, it is important that priority conservation measures are implemented in the near, rather than long term.

Protected Area coverage addresses about half of the Tarpon sites identified by this study, leaving Juvenile sites in the lower New River Lagoon and the coastal mainland between the Southern Lagoon and Port Honduras; recruitment and adult sites between the Manatee Wildlife Sanctuary and the Drowned Caye Range; and adult sites at Turneffe islands without any formal regulatory coverage whatsoever, beyond the forthcoming sport fishing regulations.

Priority Tarpon conservation measures for the near term should then entail: (1) The development and enforcement of policies concerning sea grass and wetland habitat reduction that will strategically improve conservation of the mangrove habitat on which recruiting Tarpon depend, particularly on San Pedro island, The Hicks & Riders Caye ranges, and other islands; (2) prohibition of gill netting in these specific unprotected areas as a first priority, and elsewhere over time; and (3) development and dissemination of best practices guidelines for sport fishers to insure catch & release activities do not result in chronic deterioration of adult Tarpons ability to capture prey and feed effectively.

Additionally it is important to note that the deep water spawning behavior and the lengthy larval development time for Tarpon, suggests that at least a portion of the leptocephalus larvae recruiting to the Belize population may well have been spawned elsewhere in the Caribbean, while a portion of the leptocephalus larvae spawned in Belizean waters may also be recruiting elsewhere in the Caribbean, depending on prevailing current patterns each year, which in turn points to the likely need for Tarpon stocks to be managed at the regional level to maximize effectiveness.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Tarpon
Distribution
In
Belize
Mexico
Guatemala
Honduras
Funded By:
PACT
Protected Areas Conservation Trust
Ecoworks
Green Reef
Environmental
Institute
Tarpon Runs
Juvenile Runs
Local Adult Runs
Mega Tarpon Runs
Tarpon Stations
Juvenile Stations
Local Adult Stations
Mega Tarpon
MPA's
Rivers
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Sea Grass
Coral Reef
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Regional Countries
Maya Mountains
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Mangrove Islands
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Life History-Based Threats To Sport fish In Belize:

A summary of Bonefish, Permit and Tarpon life history characteristics is shown in the Table below. Among these characteristics it is particularly important to note between-species differences in larval period and the total number of habitats on which each species depends, which are key variables in the assessment of species-specific population resilience or doubling time, and hence, their susceptibility to environmental perturbation at the hand of natural and/or man-made events.

Common Name	**Scientific Name**	**Spawning Period**	**Duration Of Laval Stage(s)** (Days)	**Length / Age At Maturity**	**Recruitment Habitat**	**Total No Dependant Habitats**	**Population Resilience / Doubling Time** (Years)
Bonefish	*Albula vulpes*	Mar - Apr	41 - 71	M: 17.4 In / 3.6 Yrs F: 18.8 In / 4.2 Yrs	Sandy Beach	4 - 5	1.4 - 4.4
Permit	*Trachinotus falcatus*	Feb - Oct	15 - 18	M: 19.0 In / 2.0 Yrs F: 21.0 In / 3.0 Yrs	Sandy Beach	2 - 3	1.4 - 4.4
Tarpon	*Megalops atlanticus*	Apr - Aug	~ 150	M: 42.0 In / 10 Yrs F: 42.0 In / 10 Yrs	Mangroves	3 - 4	4.5 - 14

Tarpon have the longest larval period of the three species examined and depend upon an intermediate number of habitats across their life history (i.e. mangroves, freshwater rivers & lagoons, open coastal marine flats & shoals and oceanic waters for spawning), while Permit have the shortest larval period, depend on the least number of habitats across their life history (sandy beaches and flats, along with promontories for spawning) and Bonefish have an intermediate value for their larval stage duration but depend on the greatest number of habitats in support of their life history development. Taken together, these considerations suggest that while Bonefish and Permit probably trade off larval development time for number of dependant habitats to achieve similar levels of resilience, Tarpon demonstrate the greatest sensitivity of the three species to environmental perturbation. Other species-specific considerations in this regard are presented as follows:

Bonefish

Bonefish are less common south of Belize City, at least as compared with northern Belize and the reported distributions of Tarpon and Permit. Juvenile and adult Bonefish appear to take up residence near to their recruitment sites; and they prefer clean shallow water sand flats that are adjacent to shorelines, dense sea grass meadows and mangroves, the latter two habitats probably serving both as feeding and predator avoidance sites. Shallow waters probably also serve in fish predator avoidance, as low angle visibility would be likely to reduce strike effectiveness. Given these considerations, and the distribution of Bonefish in Belize presented herein, it is clear that northern Belize probably offers more contiguous shoreline area for recruitment (e.g. as presented by Ambergris and the Hicks Caye ranges) than southern Belize, which is primarily populated by a few small round sand cayes offering limited recruitment area. This also appears to hold true for the Belizean atolls as well, wherein the Turneffe Islands afford the longest presentation of sandy windward shoreline found outside the Belize Barrier Reef, and also supports the greatest abundance of Bonefishing sites. Important areas of research with respect to the Belizean population include species distribution; and quantitative analyses of remaining habitat in highly threatened areas; recruitment and population density per M^2 habitat; age & growth, size & age at maturity, diet, fecundity, and country/place of origin.

Permit

The windward sandy beaches of eastern Ambergris, Hicks and Riders Caye ranges and Turneffe Islands; and those of the Barrier Reef Lagoon Cayes in Central Belize appear to be the most important recruitment sites for Permit in Belize. This finding suggests Permit do not particularly require large beach targets to recruit to as appears to be the case with Tarpon and Bonefish. Juvenile and adult Permit, on the other hand, appear to enjoy similar sandy shoal habitats, and so demonstrate a relatively ubiquitous distribution across Belize, particularly west of Ambergris Caye, and in the central reaches of the country. Important areas of research with respect to the Belizean population include, as with Bonefish, quantitative analyses of remaining habitat in highly threatened areas; recruitment and population density per M^2 habitat; age & growth, size & age at maturity, diet, fecundity, and country/place of origin.

Tarpon

The mangrove lined lagoons of Ambergris Caye, particularly the San Pedro and Cayo Frances lagoons, appear to be the most important recruitment sites for Tarpon in Belize. This finding probably results from the simple fact that large recruitment sites can offer long-shore currents, such as those found on Ambergris Caye, which should be easier for current-born larvae to recruit to than comparatively smaller sites, such as the tiny cayes of the Belize Barrier Reef, which lack such currents. Juvenile and adolescent Tarpon, on the other hand, appear to enjoy a ubiquitous distribution across Belize, although they have been almost entirely extirpated from some river mouths by gill netting, particularly in southern Belize.

Adult, *non*-migrating Tarpon are generally represented at a greater number of sites in northern Belize and at Turneffe Islands than elsewhere in Belize, which is a likely result of their being a far greater number of mangrove channel sites found at these two particular locations. Interestingly, these sites do not appear to be competitively occupied by migrating Mega-Tarpon. Rather these adults appear to prefer reef cuts over mangrove channels, their displacement from the mangrove channels of southern Ambergris Caye by hurricane Keith suggesting the reason for this preference may be closely linked to current speed and/or habitat quality, while the consequence of such loss may be that the memory of the site is lost from the population forever. Important areas of research will include those identified for Bonefish and Permit for each of the two populations represented in Belize.

Local & Regional Management Recommendations

There are essentially two mechanisms of regulatory administration in Belize. These include the body of regulatory statements enshrined in the laws of Belize, and the statutory bodies that have been legally charged with the responsibility of regulatory oversight through permitting and/or enforcement. The relationship between these two mechanisms governs the absolute fate of the country's sport fish stocks and industry. Statutory protected areas in general and marine protected areas (MPA's) in particular, are designed to provide surrogate or deputy/onsite services in this regard for specific geographic extents of particular environmental and/or economic interest or importance. Within the present context then, Belize's laws are ubiquitous in their application, underlying the more specific and often times more stringent regulatory framework of marine protected areas and elsewhere standing alone where MPA's do not extend. Consequently, insightful interleaving of these two types of regulatory mechanisms will be critical to the development of an optimized conservation strategy for Belize's sport fish stocks and industry.

Existing Protected Area Coverage & Management

Existing protected area coverage addresses about half of the Bonefish and Permit sites identified by this study, leaving recruitment sites along the windward side of the Ambergris, Hicks, Riders and Drowned Caye ranges; the Turneffe Islands; and adult sites in these same areas without any statutory protection whatsoever. Protected area coverage also

address about half of the Tarpon sites identified by this study, but leave recruitment and adult sites between the Manatee Wildlife Sanctuary and the Drowned Caye Range; juvenile freshwater sites in the lower New River Lagoon and along the coastal mainland between the Southern Lagoon and Port Honduras; and adult sites at Turneffe islands without any formal regulatory coverage. Most MPA's permit sport fishing with their conservation zones (usually Conservation Zone II, or C), and as such are already empowered to managed catch and release activity, but these managers will need to be brought abreast of the recommendations of this study to insure best management practices (described below) are being observed, particularly in regard to barbless hooks; that permitted fishing zones are properly demarcated; and that fishers hold valid sport fishing licenses.

Management Needs For Unprotected Areas

The Fisheries Act (Chapter 213 in the Laws of Belize, revised 2000) itself makes no specific provision for the conservation of Permit or Tarpon. However Statutory Instrument 114 of 2009 specifically addresses this need in stating in Section 3. (1) that: *No person shall have in his possession any bonefish, permit fish or tarpon or any of its product forms, save and except in the act of catch and release.* Local shop keepers and grocers however require better advisement of this regulation in order to prevent allure of Permit sales to these markets. Statutory Instrument 115 of 2009, locally referred to as the licensing act, required that the licensing proceeds being allocated to the legislation's enforcement. Although many non-governmental organizations and private sector fishing operations supported the legislation in principle, those opposed the legislation objected to the specific requirement for *everyone* on board a fishing vessel to hold a license under penalty of fine and/or imprisonment, including non-fishing observers, tour-guides, children and elders, which ultimately led to the instruments' repeal and revision. As a result, the revised statutory instrument has been proposed to include the following key amendments:

1. A sport fishing license will now be needed by two main groups of fishermen (only). Visitors (non-Belizeans, non-permanent residents), and sport fishermen (Belizean or otherwise) who are looking to target the main sport fish species as listed in the fisheries legislation. Only the angler that is fishing will now be required to hold a valid sport fishing license. Other passengers who are not fishing will not be required to hold a sport fishing license.
2. All tour guides in Belize who possess a valid tour guide license will be exempt from the requirement to hold a sport fishing license.
3. Children under the age of 16, persons over the age of 65, and anglers who are simply fishing from a dock or pier or the sea shore will be exempt from the requirement to hold a sport fishing license.

One additional consideration in this regard might also include the prohibition of barbed lures from use in catch and release fishing, which also may be less urgent today than at a point in time 10 years hence when (and if) the industry expands 10-fold. The Fisheries Act or its corollary Statutory Instruments in and of themselves do not, however, prohibit collateral development impacts, which can also impose important sources of mortality to Belize's sport fish stocks. These types of impacts will require independent treatment under the laws of Belize.

Four specific practices by developers and fisher-folk require greater control in critical zones outside of formally enshrined protected areas. These unprotected areas include all of Ambergris Caye south of the Bacalar Chico and Hol Chan Marine Reserves; the Hicks, Riders and Drowned Caye ranges; the shoreline of the coastal mainland between Salt Creek and the Belize River; and the Turneffe Islands. The practices include:

(1) Dredging of windward shorelines and/or flats adjacent to all of Belize's cayes by resort developers and/or the Government of Belize for beach reclamation and/or land fill. These habitats are particularly important to Bonefish and Permit recruitment;

(2) Lease or sale of sub-tidal sand flats by the Lands Department for construction of recreational residences. These habitats are particularly important to all three sport fish species for foraging;

(3) Mangrove and sea grass removal from private shorelines by resort developers. These habitats are particularly important to juvenile and adult Bonefish for foraging and Tarpon for recruitment; and

(4) Gill netting perpendicular to shorelines and across river & creek mouths, sea grass meadows and/or mangroves by fisher-folk. These habitats are particularly important to Bonefish and Tarpon for foraging.

Dredging activities are principally governed under the aegis of the Mines & Minerals Act, Chapter 226 in the Laws of Belize (Revised 2003), with respect to quarry or mining of construction materials, particularly sand, from river or sea beds (e.g. see interpretations for construction, industrial and quarry materials). As such, there is no particular regulation as to where quarry activities may take place, beyond a single reference to a distance from a property line of 1.5 (times) the depth of excavation of unconsolidated materials (see Section 34). The Act does however go on to note in Section 119 that persons using low technology sand collections from the sea floor in waist high waters shall pay half the scheduled price for a quarry permit.

Consequently, the Mines and Minerals Act should be amended to specifically prohibit (1) the removal of sea floor sand from any shoreline serving as a Bonefish and/or Permit recruitment site; and (2) the removal of sea floor sand from flats that are recognized sport fishing sites. Where dredging is deemed to be of nominal direct impact to sport fish stocks, dredging practices should be guided by a similar measure as applied to property lines, which is to say the entire flat should not be removed, but rather one or more 'holes' should be excavated toward the interior of the flat, leaving the margin of the flat intact so it can serve as habitat for sport fish and other species of marine life.

Lease or sale of sub-tidal sand flats is permitted under The National Lands Act, Chapter 191 in the laws of Belize (Revised 2003), which defines ‘national land’ to mean all lands and sea bed, other than reserved forest within the meaning of the Forests Act, including cays and parts thereof not already located or granted, and includes any land which has been, or may hereafter become, escheated to or otherwise acquired by the Government of Belize; or otherwise classed severally as town lands, suburban lands, rural lands (including pastoral lands), mineral lands, and beach lands. The Act empowers the Minister responsible for lands, among other things, to dispose of National Lands by sale, grant, lease, or license, and may otherwise alter, vary or add to the ordinary terms and stipulations upon which any grant, lease or license is made, should it be considered expedient to do so in any special instance. The Act should be amended to specifically prohibit the lease or sale of any sub-tidal sand flat for construction of recreational residences that is a recognized sport fishing site.

Mangrove cutting activities are presently defined by the mangrove regulations enshrined within the Forests Act, Chapter 213 in the Laws of Belize (Revised 2003). These regulations provide for a minimum cut area that may be modified by petition, but nowhere in the regulation is a maximum cutting limit set that must be preserved, which at the same time is beyond compromise by regulators. On Ambergris Caye, mangrove stands are being significantly reduced by developers who are happy to request permits from local regulators and to pay the minimal cutting charges since the authoritative language of the act imposes no penalty for permitted activities.

Consequently, we recommend that the Mangrove Regulations as stated in the Forests Act be amended to proscribe a maximum allowable cutting limit for Red Mangroves (*Rhizophora mangle*) as a fixed percent along the waterline of any

single property holding outside the jurisdiction of any marine protected area, be it private or public land, which cannot be compromised by regulators or permitting; with violation of the limit requiring payment of a significant fine and immediate site remediation. Further, as there are no regulatory actions currently proscribed under the Fisheries or Forests Acts for protection of sea grass beds, the two habitats might be combined under a single statutory instrument (e.g. Mangrove and Sea Grass Regulations), with sea grass habitat having a similar maximum allowable cutting limit and with similar penalty charges. Subsequently, such changes can be communicated to governmental and municipal regulators, as well as potential and existing developers alike under, for example, a *Save Half For Nature* program that also provides for the issue of a small compliance certificate to developers for following program guidelines.

Gill netting activities are presently regulated in Part 2 of the Fisheries Act, Chapter 213 in the Laws of Belize (Revised 2000). These regulations call for the following constraints on gill (stop) net use:

8. (1) In all areas outside the Barrier Reef and within a radius of two miles of the mouth of the Belize River, Haulover Creek and Sibun River, no person shall take fish by means of any beach seine, trap, weir or stop net.

   (2) No person shall with intent to take fish, use any trap or other device constructed of net or wire in any area within a distance of one hundred yards of the Barrier Reef.

   (3) No person shall with intent to take fish use any trap, wire or net, other than lobster traps, in the vicinity of Buttonwood Caye, Caye Glory, Maugre Caye or any area in which the trapping of fish is prohibited

15. (1) Subject to paragraph (2) of this regulation, no person shall take any fish in the waters of Belize with a net constructed of a natural or artificial fiber the mesh size of which is less than three inches.

17. No beach seine, trap, weir, or stop net shall be set, hauled or otherwise used for the purpose of taking **fish** at any place situated within a distance of half a mile from any city, township, village, settlement or other inhabited locality in Belize:

26. No person shall close off a channel, passage, entrance, or small embayment of water with any fishing device in such manner as to restrict the free passage of boats or to wholly prevent the passage of fish.

This existing regulatory framework will require gradual revision over time (perhaps a 3 - 5 year period) in order to achieve unilateral compliance with a comprehensive ban of gill netting in Belizean waters. Undertaking a gradual approach to the elimination of gill netting will allow the few fishers nearing retirement age to continue to earn their livelihood from gill netting, while providing time for younger fishers to find an economic alternative for the activity. The Fisheries Act can be amended or revised in support of a gradual step-down plan by first limiting gill nets to 200 ft in length, and prohibiting their placement in fresh waters altogether, and marine waters having less than 4 ft depth. Subsequently, the issue of gill-netting permits can be limited to annual periods for Belizean nationals only, there-in providing an inventory of current gill-net holdings in Belize, as well as a practical timeline for the prohibition of gill net imports and eventual prohibition of gill net possession altogether.

Ideally, sport fish stocks might best be protected from habitat degradation *and* gill netting by combining the above recommended regulatory measures with the formation of at least two and possibly three new marine protected areas, spanning: (1) from the Barrier Reef east of Ambergris Caye, Long Caye, Hicks Caye, Riders Caye, and the Drowned Cayes (range) to the coastal mainland between Salt Creek and the Belize River; (2) the entire extent Turneffe Islands Atoll (provided adequate provision can be made for select land fill needs); and (3) the entire Belize Barrier Reef platform south of English Caye (Grennels) channel.

Enforcement

Regulatory enforcement in regard to dredging, mangrove and sea grass removal, allowable fishing and gill netting practices is poor in Belize because departmental budgets simply cannot sustain independent / in parallel expenditures for patrol of the coastal zone, which are likely in excess of USD 1 million per annum, inclusive of training, maintenance and operating costs. The recent funding and development of the Belize Coast Guard for improved drug interdiction however has also provided for armed patrol of the entire Belize coastal zone. Empowering the Belize Coast Guard as deputy rangers of the Fisheries, Coastal Zone Management Authority, and Forestry departments for the cost of training in the regulatory frameworks of their enabling legislation, and in working with tourists, might well result in a practical and cost effective solution to enforcement of sport fishing and related conservation oriented legislation.

Best Practices Guidelines

Catch and Release can be a valuable conservation tool, but just because a fish swims away when released doesn't mean it continues to thrive in its pre-capture state. By practicing good angling habits, sport fishermen can greatly increase the chances that the fish they catch and release will survive, and every angler can positively influence the future of Belize's sport fishing resources by striving for 100% survival of all released fish. The following Best Practices recommendations have been adapted from those written for Bonefish by the Bonefish and Tarpon Trust, and Best Practices for Catch and Release by the Florida Fish Wildlife & Conservation Commission:

Hooks: The type of hook, hooking location and time taken to remove a hook all affect sport fish survival rates.

- Always use barbless hooks. The time spent struggling to get a barbed hook out impacts the survival of the fish. Barbed hooks also have a greater chance of damaging the fish during removal. If you do not have barbless hooks, flatten the barbs with pliers. Multi-hooked lures or stainless steel hooks should *not* be used.
- Use non-offset circle hooks when fishing with natural bait to avoid gut-hooking a fish – circle hooks tend to hook fish in the jaw, making them easy to remove.
- If a hook is deep in a fish's throat or stomach, cut the line as close as possible to the hook – the hook (non-stainless steel) will eventually dissolve inside the fish.

Fight Time: Shorter fight times increase survival rates; fish fought to exhaustion are more vulnerable to predators.

- Tackle should be heavy enough to match conditions and the size of fish so that fish can be landed quickly to reduce exhaustion, but *not* until their head can be lifted slightly above the water surface and their movements controlled.
- Always land a fish before it becomes exhausted and loses equilibrium when released (fish cannot swim and either nose dives or rolls over).
- If a fish loses its equilibrium, revive it until it can swim upright.
- High temperatures can dramatically impact the speed at which exhaustion occurs; in warmer waters reduce fight time and handling time.

Handling: Minimize handling of all fish. Over handling/improper handling may cause harm to fish.

- Handle fish as little as possible and only with wet hands, *never* with a towel. Don't squeeze the fish hard when handling it.
- *Never* place a fish on the boat deck or on the ground. This may damage fish scales or remove the fish's protective slime coating.

- Use hemostats or pliers to quickly remove hooks while keeping the fish in the water.
- Avoid lifting a fish from the water by a line. If a fish must be lifted from the water, support its weight horizontally.
- Avoid lifting a fish by its jaw, especially large fish. This can injure the fish so it can't feed normally and/or harm its internal organs.
- *Never* hold a fish by its gill cover. Never put hands or fingers in gills or eyes.
- If a net is needed to remove a fish from the water, use a knotless, soft mesh net. The mesh must be wet. Keep the fish in the water with the net.
- Avoid exposing fish to air, even when taking a photo. It's best to take pictures of a fish being released while it is in the water.
- If a fish must be held out of water, limit it to a maximum of 15 seconds.
- If lip gripping devices are used, it is best to use them only to restrain a calm fish in the water while removing the hook.
- If a fish's weight is desired, cradle the fish in a small sling and suspend the sling from the device. For larger fish simply measure the length and girth of the fish (tarpon) while it is in the water and use a measuring chart to calculate the weight. (e.g. see the Tarpon weight calculator chart, Tarpon and Bonefish Trust.)
- If a fish is exhausted, revive it before releasing it by passing water over its gills – move it forward in the water with its mouth open, or support the fish facing into the current until it has recovered.
- Gently release a fish head first into the water.

Predators Survival of released fish decreases significantly when predators are near and abundant. Predators often attack soon after a fish has been released.

- If you have caught a fish and potential predators are near, consider using a live well to hold the fish for a short time to allow releasing it some distance away from predators.
- When predators become abundant and appear to be attracted to your fishing activity, consider moving to another fishing location. Exhausted fish are much more vulnerable to predators and are six times more likely to be attacked.

Regional Management Needs

The deep water spawning behavior and the lengthy larval development time for the three species of sport fish being evaluated by this study suggests that at least a portion of the Bonefish and Permit larvae recruiting to the Belize population may well have been spawned along the eastern coast of Yucatan Mexico, while a portion of the larvae spawned in Belizean waters may be recruiting to southern populations in Guatemala, Honduras, Nicaragua, Costa Rica and/or Panama, depending on prevailing current patterns each year. In the case of Tarpon, the originating and destination populations of larvae may be more widely disbursed throughout the greater Caribbean. These findings in turn point to the likely need for sport fish stocks to be managed at the regional level to maximize effectiveness. To achieve this end, the findings of this study should be circulated to the fisheries departments of the adjacent states, and an initiative should then be put forward to ratify a regional protocol for the management of sport fish stocks common to the western Caribbean states. Ultimately, each signatory to the protocol will be charged with amending the appropriate legislative acts in their respective countries, with the end result being the implement of an appropriate, regionally based management scheme for the sport fish species examined by this study.

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