

**The Last Island: An Invasion of the Lionfish (*Pterois* spp.)
in Trinidad and Tobago (Southeastern Caribbean)**

**La Última Isla: Una Invasión del Pez León (*Pterois* spp.)
en la Isla Trinidad y Tobago (Sureste del Mar Caribe)**

**La Dernière Île: Une Invasion de la Rascasse Volante (*Pterois* spp.)
à Trinidad et Tobago (le Sud-est de la Mer des Caraïbes)**

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ABSTRACT

During the first two years (2013 - 2015) of the lionfish invasion in Trinidad and Tobago, a culling programme was implemented, with collections occurring at monthly intervals. Lionfish were captured, and comparisons were made of the length-weight relationship (LWR), size modality, population densities and sex ratio of the sub-populations determined at different localities around the island. One thousand and eighty-six (1086) lionfish were collected with some areas, especially on the Leeward coast showing densities > 200 individuals/ha. The modal size class increased from 15 - 19.9 cm in the first year to 20 - 29cm in the second year (year 2). Females represented more than 60% of all fish sampled, however males were generally longer and heavier than females. At sites where culling was less frequent, higher densities (up to 4x) and larger size modalities of lionfish were noted than on frequently culled sites. As the invasion continues, the species most threatened include small and medium bodies fish, with the following representing the most frequently scored prey item: *Stegastes partitus*, *Sparisoma aurofrenatum*, *Stenopus hispidus* and *Neogonodactylus curacaoensis*. There has been no noticeable negative impact observed on any of the study reefs thus far.

KEY WORDS: Invasive species, Lionfish (*Pterois*), population density, L-W relationship, reef fish

**Preliminary Observations of Lionfish Behavior and Attraction
for Lionfish Aggregating Devices (LADs)**

**Observaciones Preliminares del Pez León Comportamiento y de Atracción
para Lionfish Dispositivos de Concentración (LADs)**

**Observations Préliminaires de Lionfish Comportement et Activité
pour les Dispositifs de Concentration de Lionfish (LADS)**

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ABSTRACT

The majority of lionfish control has been through diver-based removals. This strategy is successful at reducing densities and minimizing impacts on specific reefs. However, due to costs, limited bottom time and operable depths, this alone is not an effective large-scale (kilometers of reef) control technique. Lionfish exhibit high association with a variety of natural and artificial structures. Observations in Florida, Gulf of Mexico, and The Bahamas suggest lionfish may actually prefer artificial structure over natural. Based on these observations, we hypothesized that artificial structure could be used to attract lionfish and aggregate them around the structures. To test this hypothesis, we are experimentally testing two Lionfish Aggregating Device (LAD) types (a vertical and horizontal design) across several kilometers of seagrass, patch reef, continuous coral reef, and hard-bottom habitats in the Florida Keys and North Carolina. To support field work, we are conducting laboratory trials in 15,000 and 30,000 liter aquaria to test lionfish preference for different LAD designs and various attractants (sounds, decoys, and lights). Preliminary laboratory results, based on nine individual (single lionfish) and

nine group (five lionfish) trials, suggest lionfish do have strong preference for one structure over the other, but preference changes as the number of lionfish increases. If successful, LADs will provide an opportunity for spearfishers to perform targeted removals, particularly at deeper depths. Managers will be able to incorporate LADs into ongoing control strategies. LADs would allow for control across several kilometers of habitat and will help maximize efficiency in areas where resources are limited.

KEY WORDS: Lionfish aggregation, large-scale control, lionfish behavior

Efforts to Trap Invasive Lionfish Near Boat Docks on Little Cayman

Los Esfuerzos para Atrapar Lionfish Invasor Cerca de Muelles en Pequeño Caimán

Les Efforts pour Piéger Lionfish Invasive Près de Quais sur Little Cayman

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ABSTRACT

Indo-Pacific lionfish, *Pterois* spp., have established themselves in the western Atlantic Ocean and Caribbean Sea, and were first reported around Little Cayman in 2008. Weekly culling efforts focus predominantly on coral reefs and neglect shallow water habitats such as seagrass beds. The efficacy of two trap designs at capturing lionfish near boat docks bordering seagrass beds was evaluated. Over a 32-day period, two lionfish were captured in small 18 cm minnow traps, and one was captured in a 91 x 61 x 38 cm shaded fish pot. Eight juvenile lionfish were captured using hand nets at the completion of the study. All lionfish captured were sexually immature, had an average total length of 94.55 ± 23.90 mm, and an average weight of 10.75 ± 7.93 g. Minnow traps had an average bycatch incidence of $18.52 \pm 7.86\%$ per site with an average of 0.296 ± 0.374 bycatch individuals per trap per day. Shaded fish pots had an average bycatch incidence of $35.54 \pm 18\%$ per site with an average of 1.37 ± 1.46 bycatch individuals per trap per day. Lionfish sightings at study sites decreased as water temperatures increased. Results indicate that trapping of lionfish in seagrass habitats using minnow traps or shaded fish pots is not a resource-efficient culling method. The small size and sexual immaturity of the lionfish captured confirms previous observations that juvenile lionfish utilize seagrass beds. The protection of juvenile native species from lionfish predation should be a priority of management goals. Next steps include determining the recruitment rate of juvenile lionfish and investigating the use of aggregating structures to increase the efficiency of hand netting.

KEY WORDS: Lionfish, traps, Little Cayman, juvenile lionfish, trap bycatch

Mapa de Riesgo sobre la Invasión de Pez León en el Caribe Mexicano: Repercusiones y Oportunidad de Desarrollo

Risk Map of the Lionfish Invasion in the Mexican Caribbean: Impact and Development Opportunity

Carte des Risques de L'invasion de Rascasse Volante dans la Mer des Caraïbes : Impact et Opportunité de Développement

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RESUMEN

El pez león (*Pterois volitans* / *miles* complex) es una especie invasora que desde su primer registro en el gran Caribe, a amenazado la integridad y biodiversidad de los ecosistemas. El pez león se ha convertido en una década, en una de la especie invasora mas exitosas, afectando de forma inconsistente y aun poco valorada, los ecosistemas arrecifes del Caribe mexicano. Se presenta un mapa de riesgo con en análisis de los datos sobre la invasión de pez león en los sitios de estudio

de la zona norte, centro y sur del Caribe mexicano. La densidad poblacional de peces promedio por hectárea es heterogénea en la región, la abundancia de peces no varía significativamente entre los sitios, pero sí es significativa en un perfil de profundidad vertical a la línea de costa. El número de organismos por hectárea en el ANP de Banco Chinchorro, zona sur (con alto nivel de conservación), es similar al reportado en Playa del Carmen, zona centro (sin estatus de conservación), presentando en ambos sitios las mayores tallas y abundancias. En Isla Contoy y Punta Nizuc (nivel medio de conservación), zona norte, la abundancia es menor con respecto a la zona centro y sur. No hay correlaciones entre la densidad de la especie invasiva, la complejidad de fondo o la biodiversidad entre zonas. Los resultados del análisis reflejan que se aplican esfuerzos de control de la especie invasiva disímiles en cada zona. Se recomienda intensificar los esfuerzos de control de la especie mediante su consumo y al mismo tiempo trabajar hacia una estrategia de manejo integral única con un enfoque ecosistémico, donde la conservación de especies locales, magnifiquen el control.

PALABRAS CLAVE: Pez león, especie invasora, Caribe mexicano, ANP, biodiversidad

Relationship Between Habitat Complexity and *Pterois* spp. Densities in Parque Nacional Marino de Punta Francés, Isla de la Juventud (Cuba)

Relación Entre la Complejidad del Hábitat y las Densidades de *Pterois* spp. en el Parque Nacional Marino de Punta Francés, Isla de la Juventud (Cuba)

Relation Entre la Complexité de L'habitat et Densités de *Pterois* spp. dans le Parque Nacional Marino de Punta Francés, Isla de la Juventud (Cuba)

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ABSTRACT

The substantial costs involved in the eradication of the invasive lionfish (*Pterois volitans* and *P. miles*) leave physical control measures (culling) as the only viable option to limit their populations and associated impacts. To maximize culling effectiveness, identification of habitat types or characteristics most correlated with lionfish presence would be beneficial. Reef complexity in particular is a characteristic that is expected to affect lionfish numbers. This study investigated variations in lionfish densities across habitat types of different complexity and attempted to determine at which scale (site vs. structure) complexity best correlates with lionfish presence and abundance. The seven study sites in the Parque Nacional Marino de Punta Francés, Isla de la Juventud (Cuba) included different habitat types such as patchy reefs and reef slopes. Lionfish density for each site was calculated as the average number of individuals found inside three 30 x 30 m sample areas. The same areas were sampled for rugosity, a proxy for habitat complexity, by taking a measurement every 5 m along six 30 m transects. Rugosity was also measured for every spot where lionfish were found inside the site. Preliminary analysis indicates that site-scale habitat complexity does not significantly affect lionfish presence or density. At a structure scale, however, lionfish appear to preferentially occupy highly complex reef elements such as overhangs where they often congregate. These preliminary results suggest that focusing culling on sites where these structures are present, rather than across more generic habitats, would maximise culling effectiveness.

KEY WORDS: Lionfish, Cuba, habitat preferences, lionfish control, invasion management

Stakeholder Perceptions on Lionfish (*Pterois volitans*) as a Threat to the Ecosystem and on its Viability for Human Consumption in Quintana Roo, Mexico

Percepción de Usuarios sobre El Pez León (*Pterois volitans*) como Amenaza al Ecosistema y sobre su Viabilidad para Consumo Humano en Quintana Roo, Mexico

Perceptions des Parties Prenantes sur Lionfish (*Pterois volitans*) comme une Menace pour L'écosystème et de sa Viabilité à la Consommation Humaine Quintana Roo, Mexique

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ABSTRACT

The invasion of red lionfish, *Pterois volitans*, in the Atlantic Ocean has generated high concern among scientists, managers, and users. Environmental authorities have responded to the invasion by promoting lionfish consumption as a measure of population control. The present study aimed to describe, through questionnaires, interviews, and non-participant observation, perceptions of local stakeholders (fishermen, restaurant owners, and fish consumers) on the lionfish as a threat to the marine ecosystem and its potential for human consumption. This work described, for the first time, the stakeholder's perceptions in two coastal localities (Cozumel and Puerto Morelos) in the Mexican Caribbean where lionfish has been traded and consumed. Results showed no differences between stakeholder's opinions from the two localities in part because these stakeholders recognize the problem of lionfish as a threat to the ecosystem, have high willingness to consume it, and consider it a useful resource for the local economy. The limiting factor for lionfish consumption among stakeholders is the high cost of its fillet. The establishment of a market, with low expectations, may originate negative outcomes for addressing the lionfish invasion. As consequence, stakeholders may have different perceptions which may undermine efforts to manage the invasion. Public opinion can be a useful tool to understand the socio-ecological context of stakeholders to face a biological invasion in order to improve the establishment of future control strategies of marine invasive species in the region.

KEY WORDS: *Pterois volitans*, public perception, Yucatan Peninsula, lionfish consumption

Changes in Lionfish Prey Consumption

Cambios en el Consumo de Pez León Presa

Modifications dans la Consommation de Proies Lionfish

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ABSTRACT

The invasion of the Atlantic waters by the Indo-Pacific lionfish (*Pterois volitans*) began in the early 1990s off the coast of Florida. By 2008 the invasive lionfish made its way to the US Virgin Islands. On November 25, 2008 the first confirmed Indo-Pacific lionfish was removed from Frederiksted Pier on St. Croix, US Virgin Islands. Currently, the lionfish populations in the US Virgin Islands are well established and have spread down the Lesser Antilles toward South America. This study investigated potential temporal and spatial changes in prey consumption by lionfish culled from reefs surrounding St. Croix. After observing gut contents of 542 lionfish in 2011 that were collected from the west end of St. Croix and 86 lionfish from the northeast end in 2013, results indicated that lionfish preferred the same top three prey items, regardless of location.

KEYWORDS: Lionfish, St. Croix, prey consumption, stomach contents, invasive species

Lionfish Control in Areas Inaccessible to Fishers: Counting and Culling with the Help of Conservation Volunteers

El Manejo de Pez León en Zonas Inaccesibles por Pescadores: Monitoreando y Controlando con la Ayuda de Voluntarios de Conservación

Le Controle du Poisson-lion en Zones Inaccessible aux Pecheurs: Compter et Supprimer avec L'aide de Bénévoles de la Conservation

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ABSTRACT

In Belize, targeted fishing is gaining momentum as the most cost-effective method to control invasive alien lionfish by suppressing population numbers to or below site-specific threshold levels. However in the country's marine reserve no take zones (NTZs) or deep reefs (> 18 m) where commercial fishing is either not permitted or impractical, there is a need for alternative means of lionfish control. This study evaluates a lionfish control programme that enlists the help of conservation volunteers to monitor lionfish populations and support removal efforts using regular SCUBA culls, an initiative that began in January 2011 in Bacalar Chico Marine Reserve (BCMR), northern Belize. We observed a significant upshift in lionfish population size structure between 2011 and 2012 suggesting that lionfish would soon enter the exponential growth phase typical of expanding invasive alien species populations. However, population size structure has since stabilised, and sighting per unit effort (SPUE) data collected over the 4 years since the culling program began suggest that the rate of population expansion has slowed. Our results suggest that although regular culling efforts have not reduced abundance in BCMR, they may have prevented the lionfish population from entering exponential growth. We discuss the potential for volunteers to support lionfish monitoring and control efforts in NTZs and present preliminary lionfish population density estimates recorded by volunteers in another NTZ in southern Belize that highlight the need to develop similar lionfish control strategies in areas inaccessible to fishers across Belize's marine reserve network.

KEY WORDS: Lionfish, *Pterois volitans*, invasive alien species, control, Belize

An Assessment of the Lionfish Population Density in Discovery Bay, Jamaica

Una Evaluación de la Densidad de Población Lionfish en Discovery Bay, Jamaica

Une Évaluation de la Densité de Lionfish Population à Discovery Bay, Jamaïque

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ABSTRACT

Lionfishes, *Pterois volitans* and *Pterois miles*, were first recorded on the north coast of Jamaica in 2008. They are now found in all Jamaica's coastal waters including offshore banks such as Pedro and Morant Cays. These native species of the Indian and Pacific Oceans have now established populations along the southeast coast of the United States, the Gulf of Mexico, the Caribbean and South America. Due to their potential negative impact on fisheries and the marine ecosystem, we sought to investigate their population densities at three sites along the Discovery Bay coastline over 26 months. The lionfish population density decreased at two of the three sites surveyed. At Skeggy Reef (the westward site) and Dairy Bull (the middle site) there was a decline in the population by approximately 37% and $48\% \pm 0.95$ SE respectively. Pear Tree Bottom (eastward site) showed an increase in the lionfish population density of $52\% \pm 0.95$ SE over the same time period. The ratio of female to male lionfish was 1: 1.2 with 60% (n = 179) of the female population noted to have spawning capable to actively spawning gonads. This reduction in the population could be attributed to an increase in public education and awareness on lionfish through a national campaign promoting the consumption of lionfish as a control mechanism. Other possible reasons for the decline could be due to migration to deeper waters and behavioural changes to humans. Continued promotion of lionfish consumption is recommended to control this alien invasive fish as well as further research.

KEY WORDS: Lionfish, invasive, population, Jamaica, Discovery Bay

Densidad, Tamaño, y Dieta del Pez León *Pterois volitans* en Cuba Occidental: Prístino Implica Más Vulnerable?

Density, Size, and Diet of Lionfish *Pterois volitans* in Western Cuba: Does Pristine Imply More Vulnerable?

Densité, la Taille, et le Régime du Lionfish *Pterois volitans* dans Western Cuba: Ne Signifie Vierge Plus Vulnérables?

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RESUMEN

El pez león se reportó por primera vez en Cuba en el 2007, con registros casi simultáneos en las costas del norte y sureste. En el Parque Nacional Guanahacabibes, Cuba occidental, las primeras fechas de registro fueron en el 2009. Como en otros lugares del Caribe, su abundancia y distribución han aumentado dramáticamente. Este estudio se realizó en seis sitios de Guanahacabibes, desde 2010 hasta 2014. Seis transectos de banda de 50 × 2 m, se ubicaron en cada sitio para estimar la abundancia de peces león y la longitud individual; la biomasa fue estimada a partir de la longitud. La densidad, la biomasa y la longitud del pez león aumentaron significativamente hasta 2012 y 2013, cuando las poblaciones se estabilizaron. No hubo diferencias en la abundancia entre las localidades; por otra parte, la biomasa mostró diferencias por año y por localidad, siendo mayores en los veriles y menores en los camellones y canales. El estudio de la dieta estuvo basado en el análisis de 411 individuos adultos. Se detectaron 54 entidades alimentarias, pertenecientes a 10 órdenes y 19 familias, principalmente peces y crustáceos; las principales presas fueron Gobiidae, Pomacentridae, Mullidae, Labridae, Scaridae y Gramma spp. Esperábamos que el tamaño del pez león se incrementara más rápido que en otros lugares, debido a la falta de acciones de manejo directas contra el pez león (hasta 2015) y a la mayor disponibilidad de presas en un ambiente casi prístino; la pendiente de la curva de incremento de talla fue incluso mayor que en el oeste de Florida, pero no significativamente diferente de Xcalak, otra área protegida (Caribe mexicano).

PALABRAS CLAVE: Invasiones biológicas, áreas protegidas marinas, arrecifes coralinos, Mar Caribe, Parque Nacional Guanahacabibes

An Applied Approach to Macroscopic Gonadal Assessment in Invasive *Pterois volitans* and its Application in Citizen Science and Data Collection at Biscayne National Park

Un Enfoque Aplicada a la Evaluación Gonadal Macroscópica en *Pterois volitans* Invasiva y su Aplicación en Ciencia Ciudadana y Recopilación de Datos en el Parque Nacional de Biscayne

Une Approche Appliquée à L'évaluation Macroscopique des Gonades dans Envahissantes *Pterois volitans* et son Application dans le Citoyen de la Science et de la Collecte de Données au Parc National de Biscayne

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ABSTRACT

The study of reproductive traits of fishes can contribute to estimates of population size and to predictions of population growth or decline. While often applicable to the management and assessment of fisheries stocks, understanding a species'

reproductive traits can also be useful in the management of invasive, pest, or overpopulated species. Determination of sex and reproductive phase are primary steps in assessing population demographic parameters, and macroscopic techniques allow for low cost data collection. The aims of this study were to derive and validate a classification scheme for rapid assessment of sex and reproductive phase of lionfish in Biscayne National Park, FL. This study evaluates gonadal phase of development of male and female lionfish using high-throughput macroscopic assessment of the gonads. The results of the macroscopic evaluation of these fish, recorded using digital photography, were validated using traditional histological analysis on a subset of individuals. After validation, this macroscopic gonad classification scheme was utilized in a citizen science initiative in Biscayne National Park, where students and educators dissected and collected photographs of lionfish gonads. These photographs were analyzed, with gonads being identified for sex and reproductive phase according to the produced classification scheme. This citizen science initiative assisted in the collection of hundreds of gonad photographs, contributing to a large dataset, the analysis of which was used to describe reproductive traits, strategies, and demographic parameters of lionfish in Biscayne National Park.

KEY WORDS: Invasive lionfish, reproductive biology, citizen science, macroscopic ovarian assessment, Biscayne National Park

Recreation with a Purpose: Diving for Lionfish

Tiempo Libre con una Meta: Buceo para el Pez León

Récréation avec un Intention: Plongée pour les Lionfish (Poisson Lion)

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ABSTRACT

The rapid spread of invasive lionfish threatens marine ecosystems, challenging scientists and resource managers to develop new management tools and presenting an opportunity to engage citizens in invasive species management. In many places, recreational scuba divers have been recruited to support lionfish management efforts by providing scientists with data on where lionfish are and by removing lionfish they see. Lionfish derbies, where individuals and teams compete to capture and kill as many as they can, and community events, which provide people with an opportunity to learn more about and taste lionfish, are increasing in popularity. Engaging scuba divers in the pursuit of lionfish provides divers with an opportunity to do something positive from the environment, potentially offsetting some of the damage to reefs divers can cause. This presentation uses data from lionfish events held in Florida and in Utila, Honduras to explore how these elicit interest and participation from recreational scuba divers. Sampling lionfish, learning about the invasion, and innate competitiveness all contribute to interest in pursuing lionfish. Going forward, resource managers should build programs which capitalize on and expand this interest to maximize the number of people actively removing lionfish.

KEY WORDS: Lionfish, scuba, citizen science, engagement

Community of Fishermen Provides Relevant Data on Fisheries as Baseline Information for the Declaration of a New Coral Reef Protected Area in the Caribbean of Colombia

Comunidad de Pescadores Proporciona Datos Pertinentes sobre la Pesca como Información de Base para la Declaración de una Nueva Área Protegida de Arrecifes de Coral en el Caribe De Colombia

Communauté des Pêcheurs Fournit des Données Pertinentes sur la Pêche que des Informations de Base pour la Déclaration D'un Nouveau Récif de Corail Zone Protégée dans les Caraïbes de la Colombie

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ABSTRACT

Active participation of the community of fishermen from Carpuraná in the process of declaration of the New Marine Coral Reef Protected Area by the National Parks Authority in alliance with the Foundation ICRI Colombia. Reliable data gathered from 2009 till present is provided by PESCAPUR the Fishermen Association that join the whole community in their request for a soon improvement of management effectiveness within a IUCN Category to avoid oil spill exploration that will mean a threat to their food security depending on the artisanal coral reef fisheries and ecotourism.

KEY WORDS: Coral reefs, effectiveness, lionfish, fisheries, management

Evidence of Fishermen Controlling Deep Populations of Lionfish in Colombia: Case Study Capurgana, Choco, Caribbean Sea

Evidencia de Pescadores que Controlan las Poblaciones Profundas del Pez León en Colombia: Estudio de Caso: Capurgana, Choco, Mar Caribe

Preuve de Pêcheurs qui Controlent les Populations Profondes de Lionfish en Colombie Étude de Cas : Capurgana, Choco, Mer des Caraïbes

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ABSTRACT

This is a case study of a successful participatory scheme implemented by the Foundation ICRI Colombia at local level. Fisheries Data from artisanal fisheries show how the presence of lionfishes and the overfishing of other species have impacted the fisheries productivity.

Reliable data was gathered to feed the route for declaration of the potential new coral reef protected area, since 2008 with the collaboration of the accountant from the Fisheries Association PESCAPUR and the Network of Volunteer Observers RENOVOS (created by Foundation ICRI Colombia). Evidence of fishermen controlling deep populations will be provided with specific fishing gear and specific participatory management in the potential New Marine Protected Area (Process of declaration by the National Parks Authority in alliance with the Foundation ICRI Colombia)

KEY WORDS: Lionfish, fisheries, CPEU, community, fishermen

Relación de *Pterois volitans/miles* (Teleostei: Scorpaenidae) con Peces Depredadores Nativos en Arrecifes del Litoral Oeste de la Habana, Cuba

Relationship of *Pterois volitans/miles* (Teleostei: Scorpaenidae) with Native Predators Fish in West Coastal Reefs of Havana, Cuba

Relation de *Pterois volitans/miles* (Teleostei: Scorpaenidae) avec Poissons Prédateurs Indigènes sur Récif dans le Côte Ouest eu Habane, Cuba

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RESUMEN

El pez león (*Pterois volitans/miles*) es la primera especie(s) arrecifal del Indo-Pacífico que invade el Atlántico Occidental, constituyendo una de las invasiones de peces marinos más rápida de la historia. El objetivo de este estudio fue determinar la relación del pez león con peces depredadores nativos (pargos-Lutjanidae y meros-Serranidae) en cinco arrecifes del litoral oeste de La Habana, Cuba. Los muestreos fueron realizados mediante censos visuales con buceo autónomo entre junio del 2012 y enero del 2014 y a una profundidad de entre 10 y 12 m. La densidad y la biomasa del pez en la zona de estudio fueron mayores o semejantes que la de los pargos y meros en la mayoría de los sitios. Las mayores diferencias fueron con la familia Serranidae y las especies de esta familia *Cephalopholis fulva* y *Cephalopholis cruentata*, debido a que la abundancia del pez león fue mucho mayor que la de estas especies. Las correlaciones realizadas entre las abundancias del pez león y estos depredadores no fueron significativas, a excepción de la correlación positiva de la densidad del pez león con la densidad de pargos. Esto indica que la abundancia del pez león no es afectada y no depende de la abundancia de estos depredadores en la zona de estudio. Los pargos y meros se encuentran afectados por la sobrepesca en la zona costera de La Habana, por lo que el pez león podría desplazarlos de sus nichos tróficos e impedir la recuperación de sus poblaciones.

PALABRAS CLAVE: Especies invasoras, Caribe, impacto potencial, pez león, peces de arrecife

**Conservation of the Costa Rican, South Caribbean Sea:
Balancing a Sustainable Artisanal Trap Fishery with Invasive Lionfish Control**

**Conservacion de la Vida Marina del Caribe Sur Costarricense:
Utilizando Trapas Artesanales para la Controlar la Invasion del Pez Leon**

**Conservation de la Costa Rica, la Mer des Caraïbes du Sud:
L'équilibrage de la Pêche au Piège Artisanal Durable avec Envahissantes Contrôle Lionfish**

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ABSTRACT

The Costa Rica, Southern Caribbean (CRSC) coastline is a mélange of tropical and marine ecosystems with varied cultures and indigenous people. These ecosystems – many in marine protected areas – include poorly studied coastal lagoons, mangroves, tidal flats, coral reefs, and sea grass communities that are threatened by stressors such as raw sewage, agrochemicals, sedimentation, hydrocarbons and fishing pressure by artisanal fishing communities. The lionfish (*Pterois volitans* and *miles*), an invasive reef predator was discovered in the CRSC region in 2009. Lionfish invasions can reduce marine biodiversity and negatively affect coastal economies. The effects of lionfish on the CRSC region are currently unknown. Local natural resource agencies primarily rely on local knowledge – reinforcing the importance of local communi-

ties in ecosystem conservation. In 2011, the Association of Artisanal Fishers of South Caribbean was formed to protect the local trap fishery, improve local living conditions, and establish unified decision-making. This paper will discuss the Association's goals and methods to reduce the population of lionfish and establish a local lionfish export fishery to complement revenues generated primarily through lobster and red snapper sales, while protecting native fish stocks.

KEY WORDS: Lionfish , artisanal, trap, Costa Rica, Caribbean

Lionfish Control and Management in the Cayman Islands: Seven Years on, Lessons Learned

Control de Pez León y la Gestión en las Cayman Islands: Siete Años Después, las Lecciones Aprendidas

Lionfish Contrôle et de Gestion dans les Cayman Islands: Sept Ans Après, les Leçons Apprises

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ABSTRACT

The first lionfish (LF) was sighted in the Cayman Islands in February 2008. Thereafter, the management strategy for the Department of Environment (DOE), has been primarily concentrated on removal efforts and public education. Having restrictive local marine conservation laws, training and licensing programs had to be developed before the public was allowed to participate in removal efforts. In March 2009, with public participation and assistance from Reef Environmental Education Foundation (REEF), the DOE launched its LF control program. Cullers were licensed to use nets initially, however in late 2010 specific DOE issued spears were issued to some participants in the removal program. Additionally, cullers were required to report catch. To date over 400 individuals and 30 dive companies have been licensed to use spears across the three Cayman Islands. In September 2010, LF tournaments were started to further engage the public in removal efforts. Furthermore, in 2014, LF removal efforts were commercialized, with a company being licensed to harvest the invasive LF for export.

KEY WORDS: Lionfish, management, licensing, Cayman Islands, program

Refuges and the Control of Invasive Species

Zonas Refugios y el Control de las Especies Invasoras

Zones de Refuge et Contrôle des Espèces Invasives

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ABSTRACT

Many harmful invasive species colonize large spatial areas that include a diverse range of habitats. While a large bioeconomic literature addresses spatial-dynamics of invasive species management, limited attention is given to spatial heterogeneity of an invasion and its implications for the design of cost-effective control design. Potential sources of spatial heterogeneity include natural factors such as the local assemblage of native species. Other sources are socioeconomic, for example the distance of an area from the nearest population center. Of particular concern for management is when spatial heterogeneity leads to a refuge effect: partial or complete protection from one or more methods of control. This paper introduces a stylized spatial-dynamic bioeconomic model of invasive species management in the presence of a refuge effect. A decision maker minimizes the net present value of invasion damage and management costs by specifying control across space and time. The model is tailored to the case of invasive lionfish (*Pterois* spp.), predatory marine species known to infest deep water areas beyond the reach of control by divers. Other control techniques than can access lionfish in these depth refuges are likely to generate damage in the form of native species bycatch. Analytical results from control theory characterize the influence of economic and biological model parameters on the optimal policy. Numerical results explore the influence the refuge effect when only one control method is available, and the trade-off between invasion damage avoided and bycatch

when a second non-selective control method is introduced.

KEY WORDS: Bioeconomic, invasive species, spatial dynamic, depth refuge, lionfish

Status of the Red Lion Fish (*Pterois volitans*) in the Cayman Islands: Density, Biomass, Diets, and Size Classes Across 6 Different Habitats

Estadodel Pez León Rojo (*Pterois volitans*) en las Islas Caimán; Densidad, Biomasa, Dietas, y Clases de Tamaño a través de 6 Hábitats Diferentes

Statutde la Red Lionfish (*Pterois volitans*) dans les Îles Caïmans; Densité, la Biomasse, les Régimes Alimentaires, et les Classes de Taille à travers 6 Différents Habitats

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ABSTRACT

The invasive red lionfish (*Pterois volitans*) was first sighted in the Cayman Islands February 2008. Lionfish (LF) have been documented to indiscriminately consume large quantities of prey thereby reducing abundance of various fish species on coral reefs and its associated habitats. 105 sites were surveyed across the three island archipelago in summer 2014, in which their density, biomass, size, prey availability and prey consumed (diet) were assessed. In this study, mangroves, sea-grass beds, patch reefs; shallow terrace reefs, deep terrace reefs and deep walls of the Cayman Islands were surveyed and compared to previous years. Furthermore, density of LF in areas subjected to culling effort was assessed. LF density among islands differed, with Little Cayman (LC) having the lowest value (46.89 ± 9.41 ind./ha), followed by Grand Cayman (GC) and Cayman Brac (CB) (54.04 ± 10.01 and 83.88 ± 22.93 ind./ha respectively). Comparisons between years 2012 and 2014 demonstrated a decreasing trend in LF density across habitats, whilst recording the presence of LF in mangroves in GC and LC for the first time. GC had the lowest biomass, followed by LC, with CB showing a value threefold of GC. LF mean total length for the Cayman Islands was 25.76 ± 0.43 with largest recorded in GC of 36.2cm. Stomach content analysis showed that teleost fishes were the preferred food across islands, diet data showed a significant preference of prey eaten among the three islands; additionally prey availability did not appear to influence density of LF in any habitat.

KEY WORDS: Lion fish, invasive species, culling, Cayman Islands, coral reefs

Expansion of Lionfish Invasion in Costa Rica: A Threat Looming over Eastern Pacific Waters?

Expansión del Invasor Pez Leon en Costa Rica: Una Amenaza Sobre las Aguas del Pacífico Oriental?

Expansionde L'invasion de Lionfish au Costa Rica: Une Menace qui Pèse sur les Eaux du Pacifique Oriental?

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ABSTRACT

The first sighting of lionfish (*Pterois volitans*) in Costa Rican Caribbean reefs (April 2009), prompted immediate responses from academia, government, and local communities. Since then, local scientists have warned decision makers about potential expansions into the Eastern Pacific waters. Large-scale predictive cellular automaton models suggest that an invasion to this region would not be as successful as in the Western Atlantic. However, the academia has advised the National Commission on Lionfish Control to develop preventive and adaptive action plans, given several vulnerabilities, such as: 1) up to 97% of Costa Rican fisheries production comes from its Pacific coast; 2) lionfish ornamental value remains as high as ever, despite restrictions on import and transport of live specimens; 3) "New Panamax" canal lock design may allow longer residence and acclimation times; 4) impending construction of the Nicaragua Canal will open a new pathway for the crossover; 5) tolerance to low salinity by lionfish subadults may facilitate their survival in coastal and brackish waters; 6) frequency and intensity of enhanced swell, surge, and wave action arising from Antarctic storms have increased on Pacific near-shore waters; 7) rocky reef networks along Costa Rican shorelines may provide stepping stones for colonization; 8) regional

decision-makers' lack of awareness and management strategies and plans. Furthermore, the convenience of controlling and extracting lionfish specimens from no-take marine reserves is still under great controversy among state agencies. Under this scenario, an update on the state of knowledge and actions taken is provided.

KEY WORDS: Invasive species, *Pterois volitans*, governance, Tropical Eastern Pacific, Central America

Lionfish Management in Costa Rica: Evolution of its Governance

Manejo del Pez León en Costa Rica: Evolución de su Gobernanza

Gestion de Poisson Lion au Costa Rica: Évolution de sa Gouvernance

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ABSTRACT

The first sighting of lionfish (*Pterois volitans*) in Costa Rican Caribbean reefs (April 2009), prompted immediate responses from academia, government, and local communities. Since 2009, five stages of management have been applied. The first effort, led by the National System of Conservation Areas (SINAC) of the Environment Ministry (MINAE), established an Inter-institutional Task Force, which was based on local decision-making by resource managers; there was technical support by academia, but little to none active collaboration from local communities. The second moment was a 2-year hiatus in decision-making and action-taking, with no SINAC staff in charge of local efforts and data collection. Simultaneously, fishing communities started formalizing their standing as an organization, until the South Caribbean Artisanal Fishers' Association (APACS) was created in August 2011. During the third stage (2013 – August 2015), the Viceministry of Waters and Seas reactivated the task force, as a National Commission on Lionfish Control (NCLC), a multi-sectorial entity overseeing control, research, and impact mitigation. National and regional strategic plans were developed. Currently, control efforts are led by APACS, supported by NGO funding. An ongoing fourth step expands initiative towards international co-operation, preparations for a potential expansion threatening Central American Pacific waters, with preventive and early-response management Plan for the Pacific coast. Fifth stage: starting September 2015, NCLC will be legally formalized and its leadership returned to SINAC. The three latter phases were possible by the local communities' strong drive and improved means of intersectoral communication.

KEY WORDS: Invasive species, *Pterois volitans*, reef ecosystems, co-management, Central America

Reproductive Dynamics of the Invasive Lionfishes *Pterois miles* and *P. Volitans* in the Western Atlantic

Dinámica Reproductiva de las Millas de Pez León Invasoras *Pterois miles* y *P. volitans* en el Atlántico Occidental

Reproduction Dynamique des Poissons Lion Invasives *Pterois miles* et *P. volitans* dans l'Atlantique Ouest

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ABSTRACT

The Indo-Pacific lionfishes, *Pterois miles* and *P. volitans*, are now established along the Southeast U.S. and parts of the Caribbean. The reproductive mechanisms underlying this unprecedented invasion are largely unknown. For this reason, the characteristics of lionfish reproduction, including size at maturity, spawning seasonality, batch frequency, and fecundity were estimated from lionfish collected from the temperate (the Carolinas U.S.A.) and tropical (Bahamas) regions of their new Atlantic range. Fifty percent of male lionfish were sexually mature at ~ 100 mm total length (TL), while 50% of female lionfish were mature at ~180 mm TL. Lionfish spawn throughout the year with peak spawning during summer. Estimates of lionfish batch frequency were 3.6 d for North Carolina and 4.1 d for the Bahamas. Fecundity estimates confirmed that lionfish are capable of releasing over two million eggs per year. This work provides the first comprehensive assessment of reproductive parameters of the pteroinae and valuable insight into the reproductive potential of invasive lionfish.

KEY WORDS: Lionfish, reproduction, western Atlantic, fecundity

Lionfish Feeding Ecology in Cozumel Marine Park

Ecología Alimentación Pez León en el Parque Marino de Cozumel

Lionfish Écologie Alimentaire dans le Parc Marin de Cozumel

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ABSTRACT

This study examined the stomach contents of lionfish (*Pterois sp.*) captured during a lionfish derby in the Cozumel Marine Park in Cozumel, Mexico. The study was performed as part of a binational collaborative effort to monitor the impacts of the invasive lionfish in Cozumel. The goals of the study were to describe the general characteristics of lionfish feeding ecology within the park and to identify local species at risk from predation by lionfish. As this study is the first step in a multi-year diet monitoring effort, the derby-based methodology for performing lionfish diet studies in the park was also evaluated to identify areas in which data collection and analysis can be improved in future replications of the study. Lionfish captured in the park consumed mostly fish, followed by shrimp, crabs, and other decapod crustaceans. Crab prey were observed in 24.4% of the stomachs examined, considerably more frequently than in other studies of coral reef-associated lionfish diet. Fifteen families of fish and four families of decapods were identified in the stomach contents, several of which have significant commercial or ecological value to habitats of the tropical Western Atlantic. Incongruities between the findings of this diet study and those of previous lionfish diet studies suggest both necessary changes to the diet analysis methodology as well as novel aspects of lionfish feeding ecology that warrant future study.

KEY WORDS: Lionfish, Cozumel, feeding ecology, diet shifts

Lionfish in Cuba: Diet Composition and Trophic Competition

El Pez León en Cuba: Composición de la Dieta y Competencia Trófica

Lionfish à Cuba: Composition du Régime Alimentaire et la Concurrence Trophique

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ABSTRACT

El pez león (*Pterois volitans/miles*) es originario del Indo-Pacífico y ha invadido el Atlántico occidental. Sus poblaciones causan afectaciones en las comunidades de arrecife de coral mediante depredación directa de peces e invertebrados nativos. Con la finalidad de estudiar la composición de la dieta del pez león y su competencia con peces nativos de nivel trófico similar se capturaron 229 peces león y 72 individuos de 14 especies competidoras en tres localidades de Cuba. Se analizó el contenido de sus estómagos mediante los métodos numérico, frecuencial, volumétrico e índice de importancia relativa. Se identificaron 49 entidades alimentarias distribuidas entre grupos principales: peces, crustáceos y moluscos, en este orden de abundancia, excepto en la localidad de Guanahacabibes donde las especies competidoras mostraron preferencia por los crustáceos. Se calculó el índice de Morisita-Horn para determinar el grado de solapamiento entre la dieta del pez león y las especies competidoras. Este índice varió según el biotopo marino (seibadal y arrecife) ya que tanto el pez león como los competidores son considerados depredadores especialistas-oportunistas, de acuerdo al índice de Levin, dado que se alimentan de las presas disponibles y más abundantes en su hábitat. Todo lo anterior justifica que no exista una competencia ecológicamente significativa entre el pez león y los peces nativos de nivel trófico similar.

KEY WORDS: Pez león, dieta, competencia interespecífica

A Meta-Analysis of Invasive Lionfish Diet Throughout the Temperate and Tropical Western Atlantic

Un Meta-análisis de Invasiva Pez Leon Dieta todo el Templadas y Tropicales del Atlántico Occidental

Une Méta-analyse de Envahissantes Poisson Lion Régime Alimentaire tout au long de la Tempérées et Tropicales de l'Atlantique Ouest

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ABSTRACT

Invasive lionfish (*Pterois volitans/miles*) have become one of the most abundant top reef predators in the temperate and tropical western Atlantic. The impact of their invasion is not yet fully understood, but current research efforts are documenting their ecological and economic impacts through lionfish diet studies. The goal of this project is to characterize and compare lionfish feeding ecology throughout the invaded range. Our meta-analysis will help identify potential diet trends and prey preferences, as well as help determine relative ecological and commercial impacts of lionfish across space. Lionfish diet data collected throughout the invaded range was obtained from over twenty researchers for inclusion in a Microsoft Access database, and an Access-based analysis tool was created to perform analyses across datasets. Preliminary analyses have been performed on existing datasets to establish the feasibility and reliability of our analysis methods, and preliminary results do indicate distinct differences between lionfish diet in the northern reaches of the invaded range to those of the more tropical regions. As the invasion continues, having a better understanding of lionfish dietary trends will help managers triage control and management strategies.

KEY WORDS: Longitudinal diet trends, economic impacts

The Effect of Lionfish Removal on Caribbean Coral Reef Communities at Roatan, Honduras

Elefecto de la Eliminación del Pez León en las Comunidades de Arrecifes de Coral del Caribe Roátan, Honduras

L'effet de L'élimination de la Rascasse Volante sur les Communautés de Récifs Coralliens Caribéennes à Roatan, Honduras

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ABSTRACT

A pressing concern in the Caribbean is the invasion of the Indo-Pacific lionfish, *Pterois* sp. This invasive species poses a threat to native coral reef communities by competing with other predators and feeding on fish and invertebrates, some of which are commercially or ecologically important. The aim of this study was to assess the efficiency of removal efforts on Roatan, Honduras, in controlling lionfish populations and its impact on fish and benthic communities using a combination of stakeholder interviews and reef surveys. Removals were opportunistic and voluntarily performed by dive instructors and tourists, thus frequency of removals varied across dive sites. Frequent removals significantly reduced lionfish abundance to 20 fish/ha compared to 100 fish/ha at control sites and shifted size frequency distribution towards smaller individuals. On sites with no extractions, lionfish abundance was higher than snapper and grouper abundance, indicating intense competition. The abundance of prey-sized fishes, particularly from the families of pomacentride, grammatide and tetraodontidae, was positively and significantly affected by extractions. Invertivores and cleaners as functional groups showed significantly higher abundances on sites with frequent extractions. Herbivore density was similar among sites, however species richness

in scaridae was also higher, and turfalgae cover was slightly lower on sites with extractions. Functional diversity indices also indicate higher functional richness related to trophic traits. Therefore, this study shows that local management efforts can control the impact of lionfish and thereby may contribute to protect ecosystem functioning. Consequently, removal efforts should be focused on sites of high ecological value.

KEY WORDS: Biological invasion, lionfish, removal effort, ecological benefits, functional richness

A Species Distribution Model of the Invasive Lionfish Population (*Pterois* spp.) in Bermuda

Modelo de la Distribución de las Poblaciones de las Especies Invasoras de Peces León (*Pterois* spp.) en de las Bermudas

Un Modèle de Distribution de L'espèce de la Population de Poissons-lions (*Pterois* spp.) Invasive aux Bermudes

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ABSTRACT

The Pacific lionfish (*Pterois* spp.) invaded the Western Atlantic through an anthropogenic introduction off the coast of Florida in the mid 1980s. It is widely regarded as having the potential to become one of the most ecologically and economically harmful marine invasions to date. Lionfish were first observed in Bermuda's waters in 1999. Despite this, the true distribution of the lionfish population across Bermuda's reef systems is still unknown. This information is vital for effective management programs. This research attempts to address this lack of knowledge through the generation of a species distribution model (SDM) based on known lionfish presence locations and various environmental predictors. Approximately 330 presence-only lionfish observations were generated from a wider fish community census of Bermuda's mesophotic coral ecosystems (MCEs) and the Bermuda Government's lionfish catch data. Environmental predictor layers (depth, temperature, benthic habitat and slope) were generated using ESRI ArcGIS 10.3.1. The lionfish SDM was generated using MaxEnt software 3.3.3. MaxEnt is a software package primarily used for species distribution and environmental niche modelling. The R Project dismo package 1.0 - 12 provided an interface between ArcGIS and MaxEnt. Evaluation of the model consistently returns an AUC (Area Under Curve) score above 0.75. This model is the first of its kind for Bermuda and not only has the capability to model lionfish but serves as a platform for future species distribution models. It is anticipated these preliminary efforts will become a vital tool for more effective marine spatial management and *Pterois* spp. eradication programs.

KEY WORDS: Lionfish, modeling, Bermuda, MaxEnt

The Fisheries Sector – An Important Ally in Shares of Control and Monitoring of the Invasive Lionfish (*Pterois volitans*) in Marine Protected Areas in the Mexican Caribbean

El Sector Pesquero – Un Importante Aliado en las Acciones de Control y Monitoreo del Pez León Invasor (*Pterois volitans*) en Áreas Marinas Protegidas del Caribe Mexicano

Le Secteur de la Pêche – Un Allié Important dans des Actions de Contrôle et de Surveillance du Lionfish Envahissantes (*Pterois volitans*) dans les Aires Protégées Marines Caraïbes Mexicaines

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ABSTRACT

The first record of lionfish (*Pterois volitans*) in the Biosphere Reserve Banco Chinchorro (RBBCH) as well as in Xcalak Reef National Park was in 2009. Since then the density and distribution of this species have been increasing. However, due to the extension and remoteness of the mentioned reefs, large financial investment and human resources are required for the control and monitoring of lionfish. This study analyzed the importance of the fisheries sector in such activities. Between 2009 and 2014, a 14x increase in catch per unit effort (CPUE) was recorded, from 0.10 to 1.47 fish/fisher/hour, by means of freediving. Additionally, in the RBBCH a group of fishermen was trained for the catch using scuba diving; thus in 2012 and 2013 CPUE was 23.2 and 18.6 fish/diver/hour, respectively. These efforts were focused on areas related to higher abundances. Furthermore, this collaboration allowed the analysis of 594 stomachs, with an emptiness ratio of 19%; 13 fish families were identified, which constituted 62% of the diet, while 37% of it were crustaceans and 0.2% mollusks. Finally, interviews with fishers showed that everyone knows the problem and contribute to the catches during daily work, besides, a high percentage also use this product for consumption and lobster food, although do not rule out the possibility of marketing it to local restaurants. Our results demonstrate the active participation of the fisheries sector and hence the need for their inclusion in the monitoring and control strategies at the local level.

KEY WORDS: Lionfish, fisheries sector, CPUE, Mexican Caribbean, Marine Protected Area

Dieta del Pez León (*Pterois volitans*) en la Isla de Providencia, Caribe Colombia**Lionfish (*Pterois volitans*) Diet in Old Providence Island, Colombian Caribbean****Régime de la Rascase Volante (*Pterois volitans*) sur L'île de la Providencia, Caraïbes Colombien**

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RESUMEN

El pez león (*Pterois volitans*) se ha dispersado a lo largo del Caribe colombiano debido a su rápido crecimiento poblacional trayendo como resultado una reducción drástica en la abundancia de peces arrecifales. Es un depredador muy activo y voraz que se alimenta desde organismos pequeños hasta algunos considerados grandes en relación con su tamaño. Esta circunstancia representa una gran preocupación para aquellos sectores que utilizan los recursos marinos, debido a que es una amenaza para la biodiversidad íctica. Con el fin de evaluar cualitativa y cuantitativamente la dieta del pez león (*Pterois volitans*) en la isla de Providencia (Caribe de Colombia) y explorar el efecto que este pez invasor puede tener sobre los recursos nativos de importancia comercial se analizaron los contenidos estomacales de 163 individuos. En los estómagos del pez león se cuantificó un total de 391 presas, siendo identificados seis grupos de presas: decápodos, peces, crustáceos, moluscos, cnidarios y huevos. Entre los peces se encontraron nueve familias: Engraulidae, Apogonidae, Grammatidae, Labridae, Pomacentridae, Serranidae, Paralichthyidae, Monacanthidae y Gobiidae, siendo esta última familia la de mayor índice de importancia relativa. *Coryphopterus* sp. (Gobiidae) representó la mayor cantidad de individuos en una muestra. Se encontraron algunas presas en periodo de reproducción como *Thalassoma bifasciatum* (Labridae). Se hallaron 142 decápodos correspondientes a cinco familias: Palaemonidae, Penaeidae, Portunidae, Sergestidae y Solenoceridae; 2 estomatopodos, dentro de los que se destaca la familia Gonodactylidae, 1 poecilostomatoida, 3 cnidarios de la clase Anthozoa, 8 moluscos de las clases Bivalvia, Gastropoda y Polyplacophora.

PALABRAS CLAVE: *Pterois volitans*, ecología trófica, biodiversidad íctica, invasión biológica

**Potential for Introduction of the Invasive Lionfish, *Pterois volitans*,
in the Tropical Eastern Pacific across the Isthmus of Panama**

**Potencial para la Introducción del Pez León Invasor, *Pterois volitans*,
en el Pacífico Oriental a través del Istmo de Panamá**

**Potentiell pour L'introduction du Poisson Lion Envahissantes, *Pterois volitans*,
dans le Pacifique Tropical Oriental à travers L'isthme de Panama**

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ABSTRACT

Lionfish (*Pterois volitans*) have established across the Western Atlantic, and may generate significant ecological and socio-economic impacts across region. Their impacts and rapid spread across the region have led to concerns of a secondary introduction in the Tropical Eastern Pacific across Central America. In this presentation we discuss the potential for spread of lionfish from the Caribbean to the Eastern Pacific across the isthmus of Panama, focusing on the Panama Canal as a route of introduction. Lionfish have established along the Caribbean coast of Panama, and are found in shallow areas near the Caribbean entrance to the Canal, however, they have not been reported within the waterway or along Panama's Pacific coast. Their spread through the waterway depends on their ability to overcome a number of barriers, including three sets of locks and two freshwater lakes. Although lionfish can tolerate low salinity and have invaded estuaries, their inability to survive in freshwater may prevent the spread of individuals through the Panama Canal. Lionfish eggs and larvae could also be transported across the Canal in the ballast water of transiting vessels, however, it is unclear whether ballast water is a vector for the spread of this species. The Regional Strategy for the Control of Invasive Lionfish in the Wider Caribbean calls for lionfish monitoring programs across the invaded region. Given the impacts that lionfish could generate in the Eastern Pacific, however, additional monitoring programs should also be implemented in areas outside the invaded region that are at risk of secondary introductions.

KEY WORDS: Lionfish, Panama Canal, ballast water, Caribbean

Estimating the Density of Lionfish *Pterois volitans* in Six MPAs Along the Mexican Caribbean

Estimaciones de la Densidad de Pez León *Pterois volitans* en Seis AMP Del Caribe Mexicano

**Les Estimations de la Densité de Poisson-lion *Pterois volitans* dans
Six AMP Situées dans les Caraïbes Mexicaines**

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ABSTRACT

Since the lionfish was reported in the Mexican Caribbean (01/2009, Cozumel), there has been concern regarding their impacts on coral reefs and their economic consequences. This prompted a regional work-plan to reduce lionfish abundance through extraction by staff and volunteers, derbies and commercial fishing. Marine protected areas (MPAs) provide conditions to study ecological processes, given that anthropic factors are lessened. We present the results of a survey aiming to estimate the lionfish density in six MPAs along the Mexican Caribbean. From July 2012 to March 2013, using SCUBA and free diving, a total of 306 sampling plots (25 m x 10 m) were made at Isla Contoy National Park (NP) n = 36, Arrecifes P. Morelos NP n = 35, Arrecifes Cozumel NP n = 46, Sian Ka'an Biosphere Reserve (BR) n = 62, Banco Chinchorro BR n = 68, and Arrecifes de Xcalak NP n = 59. A total of 333 lionfish were observed, mostly large (58.9%), and mid-sized (33%);

and density across MPAs averaged 43.3 ± 79.4 ind/ha ($\bar{x} \pm \text{sd}$). Among MPAs, lionfish mean density increased southwards with 24.4 ± 84.8 ind/ha in Cozumel and 75.9 ± 141.4 ind/ha in Banco Chinchorro. Depth and habitat type also varied between MPAs. Other fish and invertebrates co-occurring with lionfish were recorded. We proposed our estimates of lionfish densities as the baseline for lionfish density in these MPAs at depths ≤ 20 m. Further monitoring in deeper waters (>20 m) is crucial to lionfish management. This methodology can be applied to evaluate efficacy of the removal efforts in the Caribbean.

KEY WORDS: Invasive marine species, underwater visual censuses, fish abundance, monitoring

Novel Discoveries of Lionfish (*Pterois* spp.) Size Structure, Age, and Growth from Northeastern Florida

Nuevos Hallazgos de Estructura de Tamaño, Edad y Crecimiento de Peces León (*Pterois* spp.) de el Noreste de Florida

Nouvelles Découvertes de Taille Structure, L'âge et la Croissance des Poissons-lion (*Pterois* spp.) à Partir du Nord-est de la Floride

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ABSTRACT

Lionfish have invaded the Western Atlantic, Caribbean, and Gulf of Mexico at an unprecedented rate, with documented negative effects on native ecosystems. Scientific investigations on the impacts of lionfish have been conducted predominantly in tropical ecosystems with comparatively little research effort focused on temperate ecosystems, such as the South Atlantic Bight. Since life history parameters, especially growth rates, can vary with a suite of environmental (i.e. temperature), biological (i.e. genetic) and ecological (i.e. prey availability) factors, life history parameters of lionfish will likely vary regionally and among ecosystems. To quantify age and growth in a new region, lionfish were collected in 2013 and 2014 from northeast Florida ($n=3,949$) in coordination with multiple derby events throughout the year. Size structure was analyzed using length frequency analysis and statistical length based modeling. Length-frequency analysis revealed a clear bimodal population with two distinct cohorts, and rapid growth during summer. The best model fit 2013 and 2014 data sets independently, indicating annual differences in growth in that region ($K=0.63$, $L_{\infty}=435\text{mm}$ in 2013; $K=0.47$, $L_{\infty}=448\text{mm}$ in 2014). Overall, these results suggest lionfish in northeastern Florida have an abridged spawning season, with juveniles recruiting over a smaller timescale than in other regions, and little variation in growth rates, which has not been reported previously. Since accurate life history modeling inputs are integral to estimating necessary removal efforts, future population growth and the response of lionfish populations to management initiatives, information on lionfish life history should be collected at a finer spatial and temporal scale.

KEY WORDS: Lionfish, age, growth, population structure

Description of Larval Lionfish *Pterois volitans* (Scorpaenidae) for the Western Atlantic**Descripción de Larvas de Pez León *Pterois volitans* (Scorpaenidae) en el Atlántico Occidental****Description Larvaire des Poisson-lion *Pterois volitans* (Scorpaenidae) dans les Atlantique Occidentale**

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ABSTRACT

The invasive lionfish *Pterois volitans* (Linnaeus 1758) is widely distributed in the Western Atlantic and Caribbean. This invasion was fueled by year-round reproduction, frequent spawning behaviour, dispersal by ocean currents and lack of major predators. Among the less known aspects of lionfish ecology is basic information regarding the early life stages. Here we present the first complete series of larval description for *P. volitans* based on 109 larvae collected in oceanographic cruise during the spring of 2011 using MOCNESS, S10 and neuston nets. Although larger > 4 mm SL were initially identified following morphological characters, previously undescribed smaller larval specimens < 4 mm SL were determined on the basis meticulous observation and expertise. Taxonomic identifications were validated as *P. volitans* for 100% larvae, using the mitochondrial DNA (COI). The youngest larvae (1.5 mm SL) showed a characteristic bar pigment pattern over three quarters of the tail and a high concentration of pigment on the distal part of the pectoral fin. The largest (> 9 mm SL) had considerable head spination and large pectoral, dorsal and anal fins. We describe in detail the main characteristics (morphological and pigmentary) to identify with certainty lionfish larvae. These descriptions can facilitate identification of lionfish from plankton collections and thus reveal major spawning sites to discover dispersal and transport of early life stages of lionfish in the region. Accurate identification of larval lionfish in the Western Atlantic can help prioritize effective actions in control programs and management of this invasive species.

KEY WORDS: Larval morphology, pigmentary pattern, DNA Barcoding, larval taxonomy, Caribbean Sea