ULPGC Universidad de Las Palmas de Gran Canaria | Facultad de Economía, Empresa y Turismo

Programa de Doctorado en Turismo, Economía y Gestión

TESIS DOCTORAL

ANALYSIS OF THE POTENTIAL AND ECONOMIC IMPACT OF SHARK-DIVING TOURISM IN THE MACARONESIAN ARCHIPELAGOS

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Dª BEATRIZ TOVAR DE LA FE, COORDINADORA DEL PROGRAMA DE DOCTORADO EN TURISMO, ECONOMÍA Y GESTIÓN DE LA UNIVERSIDAD DE LAS PALMAS DE GRAN CANARIA

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Y para que así conste, y a efectos de lo previsto en el Artº 11 del Reglamento de Estudios de Doctorado (BOULPGC 04/03/2019) de la Universidad de Las Palmas de Gran Canaria, firmo la presente en Las Palmas de Gran Canaria, a……. de.....de dos mil.....

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Título de la Tesis:

"ANALYSIS OF THE POTENTIAL AND ECONOMIC IMPACT OF SHARK-DIVING TOURISM IN THE MACARONESIAN ARCHIPELAGOS"

Tesis Doctoral presentada por D. Pedro G. Gonzáles Mantilla

Dirigida por el Dr. D. Carmelo J. León y codirigida por el Dr. D. Austin J. Gallagher.

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“A mis padres”

En Memoria del Profesor Heriberto Suárez Falcón

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"El cerebro es como un chicle" (Papá, 2003)

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RESUMEN

La presente tesis tiene por objetivo contribuir a una mejor comprensión del potencial uso sostenible de los tiburones a través del turismo de buceo frente a la explotación pesquera de sus poblaciones en los archipiélagos de la Macaronesia. Este trabajo está dividido en 3 capítulos: el primero que aborda de manera general los desafíos y oportunidades para desarrollar esta actividad en toda el área de estudio; el segundo que estima el impacto económico de la única industria turística de buceo con tiburones existente en la Macaronesia; y el tercero que propone un modelo conceptual que permita calcular el potencial para el desarrollo de esta actividad en cualquier sitio de buceo en el mundo y que es aplicado como estudio de caso en potenciales sitios de buceo del archipiélago canario. El primer capítulo sirve como una introducción a las actividades relacionadas a tiburones en la región macaronésica tales como pesca, conservación y turismo. El segundo capítulo profundiza en el valor económico del turismo de buceo con tiburones en las Islas Azores y su potencial de conservación, lo cual sirve como una referencia para un posible desarrollo de esta industria en el resto de los archipiélagos de la Macaronesia. Finalmente, el tercero tiene como objetivo identificar y evaluar las áreas y locaciones potenciales para el turismo de buceo con tiburones en las Islas Canarias. La presente investigación permite entender que el estado generalizado de sobrepesca y las severas disminuciones de las poblaciones de tiburones en la región macaronésica inevitablemente darán como resultado una disminución de las capturas en el futuro cercano, lo que también podría reducir el valor económico de la pesca de tiburones. Por lo tanto, los usos alternativos no consuntivos de las poblaciones de tiburones, como el turismo de buceo, deben preferirse desde una perspectiva socioeconómica y de conservación y se ha demostrado que representa una estrategia potencialmente atractiva en los archipiélagos de la Macaronesia.

Introducción

En las últimas décadas la observación e interacción con fauna costera y marina en su hábitat natural se ha incrementado fuertemente, convirtiéndose en uno de los sectores con mayor potencial en la industria turística (Tapper, 2006; Patroni et al., 2018). A nivel mundial, se estima que el turismo de fauna silvestre está valorado en US $ 45 mil millones, con una tasa de crecimiento anual del 10% (Newsome & Rodger, 2013), mientras que la industria de vida silvestre marina se estima que genera más de $ 2 mil millones por año, atrayendo 13 millones de turistas y respaldando 13 000 puestos de trabajo (MMC, 2019). Su creciente demanda turística se puede atribuir parcialmente a la mayor promoción y conocimiento de la vida marina a partir de documentales sobre la naturaleza y reportajes en los medios impresos (Rodger et al., 2011). Junto con el crecimiento de estas actividades, también ha aumentado su investigación, centrada mayoritariamente en la impactos potenciales y actuales en las especies objetivo, experiencias y satisfacción de los visitantes, así como educación e interpretación en tours comerciales (Lück & Orams, 2020).

Las interacciones con vida silvestre marina pueden ser facilitadas por operadores comerciales, buscadas intencionalmente por individuos y grupos privados, o incidentales durante otras actividades marinas como buceo, natación, surf, kayak, etc. Las especies objetivo varían desde mamíferos marinos a reptiles, aves, peces, entre otros, y ocurre en diferentes y variados destinos costeros alrededor del mundo, como Australia, Estados Unidos, Sri Lanka, Alaska, Sudáfrica o Escocia. Por ejemplo, el turismo de fauna marina en Australia incluye la observación de ballenas, tortugas, alimentación de mantarrayas, observación de leones marinos e interacciones de nado con delfines y tiburones ballena (*Rhincodon typus*), operando en muchos lugares del país (Higginbottom & Scott, 2008; Rodger et al., 2010; McIntosh et al., 2015; DeLorenzo & Techera, 2019). Mientras que, en Escocia, por ejemplo, las actividades de

turismo de vida marina silvestre se enfocan principalmente en la observación de delfines, focas, ballenas y más recientemente interacciones de nado con tiburón peregrino (*Cetorhinus maximus*, Inman et al., 2016).

En efecto, un sector importante del turismo de vida silvestre se centra en observar la megafauna marina (Higham & Lück, 2007), y los tiburones se están convirtiendo rápidamente en importantes atracciones turísticas (Huveneers & Robbins, 2014). Este tipo de uso no consuntivo de tiburones, desarrollado por primera vez a fines del siglo XX (Topelko & Dearden, 2005), ha ido creciendo en popularidad y hoy es un fenómeno global (Gallagher & Hammerschlag, 2011). En los últimos años, los tiburones se han convertido en atracciones importantes en muchos sitios de buceo en todo el mundo, contribuyendo a las economías locales, regionales y nacionales en América del Norte, América Central y del Sur, Europa, el Gran Caribe, Oceanía, África del Norte y Oriente Medio, Asia e Indonesia. y África Meridional y Oriental (Topelko & Dearden, 2005; Gallagher & Hammerschlag, 2011; Vianna et al., 2011; Haas et al., 2017; Huveneers et al., 2017; Mieras et al., 2017; Zimmerhackel et al., 2019). La observación de estos animales en su hábitat natural, ya sea desde embarcaciones o bajo el agua con equipo de snorkel o buceo, es un nicho en el mercado del turismo marino en rápido desarrollo (Cater, 2007). Además de producir cambios positivos en el conocimiento, las actitudes y los comportamientos de conservación de los turistas (Gallagher et al., 2015; Sutcliffe et al., 2018) y hacer contribuciones significativas a las economías nacionales, los ingresos de esta industria son responsables del sustento de comunidades locales, y apoyan estrategias de conservación y gestión (Vianna et al., 2012, 2018).

El turismo de buceo con tiburones también ha visto un aumento en la atención académica. Una revisión bibliográfica de Gallagher et al. (2015) encontró que, hasta 2014, se publicaron 47 artículos de investigación originales centrados en algún aspecto de la industria del turismo de buceo con tiburones, y el 47% de estos estudios consisten en análisis socioeconómicos realizados a muchas escalas. Estos estudios generalmente concluyeron que, donde el turismo de buceo con tiburones es viable, los beneficios económicos de la conservación de los tiburones son potencialmente mayores que los que pueden lograr las pesquerías que explotan los mismos recursos (Clua et al., 2011, Vianna et al., 2011; Vianna et al., 2012; Cisneros-Montemayor et al., 2013). Por ejemplo, Cisneros-Montemayor et al. (2013) estimaron que el valor global de la industria del buceo con tiburones era de alrededor de USD $ 314 millones en 2011, lo que respaldaba directamente alrededor de 10 000 puestos de trabajo. Si bien la precisión de estas estimaciones ha sido fuente de debate (ver Brunnschweiler & Ward-Paige, 2014), muchos estudios han demostrado que el turismo basado en tiburones ha impulsado cambios en la importancia socioeconómica de los tiburones de un producto pesquero a un producto más valioso de uso no consuntivo en muchos destinos turísticos alrededor del mundo (Gallagher et al., 2015).

Las valoraciones económicas, sin duda, han desempeñado un papel cada vez más importante en la configuración de las decisiones políticas relativas a la conservación y gestión de la vida silvestre, incluidos los tiburones (Cazabon-Mannette et al., 2017; Gallagher et al., 2015). Si bien no existen medidas globales confiables del impacto económico del turismo de vida silvestre (Higginbottom, 2004), se ha empleado una variedad de métodos para estimar el impacto económico total de esta industria, desde la consideración del valor agregado de la producción hasta el volumen de los ingresos por entradas de tours o accesos, hasta la utilización de modelos de impacto macroeconómico intersectorial a través del análisis de entrada y salida (Catlin et al., 2013). En el caso del turismo de buceo con tiburones, se han realizado estudios socioeconómicos a muchas escalas, lo que brinda una visión general de la contribución de esta industria a las economías regionales y nacionales (ej., Dicken & Hosking, 2009; Clua et al., 2011; Vianna et al., 2011; Gallagher & Hammerschlag, 2011; Vianna et al.,

2012; Cisneros-Montemayor et al., 2013; Pires et al., 2016; Torres et al., 2017; Haas et al., 2017 ; Huveneers et al., 2017; Mieras et al., 2017; Zimmerhackel et al., 2019). Las valoraciones y evaluaciones económicas de este sector están bien establecidas en la literatura científica; sin embargo, las inconsistencias en los métodos entre los estudios y los retrasos entre las estimaciones pueden limitar la capacidad de comparar y combinar resultados para proporcionar estimaciones globales para la industria de buceo con tiburones (Gallagher et al., 2015).

En años más recientes, se han utilizado métodos de valoración estandarizados en varios países del mundo. Estos estudios de valoración han cuantificado los gastos directos e indirectos de los participantes involucrados en el buceo con tiburones, cuantificando métricas similares para evaluar el impacto económico de esta industria y los beneficios para los lugares donde se establece la actividad (ej., Vianna et al., 2011; Vianna et al., 2012; Huveneers et al., 2017; Haas et al., 2017; Vianna et al., 2018; Mustika et al., 2020). Siguiendo esta línea, el presente trabajo tiene como objetivo evaluar el potencial impacto socioeconómico de la industria turística de buceo con tiburones en los archipiélagos de la Macaronesia. Esta región biogeográfica que conforma las islas portuguesas de Azores y Madeira, las Islas Canarias en España y las islas de Cabo Verde, presenta una de las tasas más altas de biodiversidad marina en el Noreste Atlántico y es una zona transitoria de especies migratorias como tortugas, cetáceos y tiburones (Nieto et al., 2015). Además, en este trabajo se realiza una evaluación de la potencial expansión de la industria de turismo de buceo con tiburones en la región macaronésica y los posibles beneficios de conservación para las poblaciones de las especies objetivo que se encuentran en sus territorios.

Justificación

Los tiburones juegan un papel fundamental en los ecosistemas marinos. Al encontrarse en lo más alto de la cadena alimenticia, mantienen el equilibrio trófico de los océanos y su presencia es un indicador de un ecosistema saludable. Sin embargo, estos depredadores presentan unas características fisiológicas particulares tales como crecimiento lento y baja reproducción, lo cual los hace vulnerables a la sobrepesca. Históricamente, los tiburones, en general, se consideraban una captura incidental en las pesquerías dirigidas a otras especies más valiosas (Dulvy et al., 2017); sin embargo, en las últimas décadas la demanda global de productos de tiburón ha aumentado progresivamente, cambiando la pesca de tiburones de captura incidental a especies objetivo en muchas pesquerías (Dent & Clarke, 2015).

Los tiburones son capturados por flotas pesqueras de todo el mundo, con una estimación de hasta 100 millones de individuos por año (Worm et al., 2013). En 2015, se estimó que el mercado global de productos de tiburón generaría aproximadamente USD $ 1 mil millones comercializados anualmente (Dent & Clarke, 2015). Sin embargo, la mala regulación de las pesquerías de tiburones, incluida la práctica común de aleteo en alta mar (Chen & Phipps, 2002; Lehr, 2015; Dulvy et al., 2017), ha provocado una disminución mundial precipitada de muchas poblaciones de tiburones (Worm et al., 2013; Dulvy et al., 2014). Debido a la sobrepesca, los tiburones son actualmente aceptados en todo el mundo como un grupo de conservación prioritaria (Dulvy et al., 2014), con el 20% de las casi 500 especies de tiburones conocidas bajo amenaza de extinción, según la Lista Roja de la Unión Internacional para la Conservación de la Naturaleza – UICN (IUCN, 2013).

Si bien se utilizan numerosas herramientas de gestión pesquera para prevenir la sobreexplotación de tiburones, la implementación efectiva de estos enfoques está restringida a unas pocas especies y en países en desarrollo que cuentan con sólidos sistemas de gestión

pesquera (Simpendorfer & Dulvy, 2017; Ferretti et al., 2020). Lamentablemente, la gestión eficaz de la pesca es la excepción, no la regla para la mayoría de las regiones del mundo (Pauly et al., 2002) y, a la luz de estos desafíos, ahora se abren nuevas perspectivas económicas que pueden permitir un uso más sostenible de los tiburones como la industria turística de buceo con tiburones.

La identificación y evaluación de nuevos sitios potenciales para el desarrollo del turismo de buceo con tiburones se recomienda encarecidamente en la literatura general (Topelko & Dearden, 2005; Cisneros-Montemayor et al., 2013), particularmente en aquellas regiones que experimentan una disminución significativa de las poblaciones de tiburones debido a la sobrepesca, como en el Noreste Atlántico (Gibson et al., 2008). Sin embargo, solo alrededor del 10% de los estudios científicos publicados sobre el turismo de buceo con tiburones se han centrado en el Océano Atlántico (Gallagher et al., 2015), a pesar del alto número de operaciones de buceo con tiburones en esta región (Gallagher & Hammerschlag, 2011) y hasta la fecha ningún estudio se ha centrado en el Noreste Atlántico en particular, incluyendo la región Macaronesia.

Objetivos y Resumen de cada capitulo

El objetivo principal de esta investigación es contribuir a una mayor comprensión del uso sostenible de los tiburones a través del desarrollo del turismo de buceo en contraste con la explotación pesquera de sus poblaciones en los archipiélagos de la Macaronesia. En primer lugar, se realizó una evaluación preliminar de la situación actual del uso humano de las poblaciones de tiburones en la región Macaronesia donde se identificaron algunas evidencias de su potencial turístico, así como las principales amenazas para ciertas especies. Luego utilizando como base investigaciones y estudios de caso exitosos en el mundo sobre el uso turístico de tiburones como una alternativa sostenible a la pesca, se propuso analizar las posibilidades de desarrollo del turismo de buceo con estos animales en los archipiélagos macaronésicos. De esta manera el presente trabajo intenta cubrir el vacío de investigaciones sobre el turismo de buceo con tiburones, y sobre tiburones en general, en esta región del Noreste Atlántico, contextualizando y describiendo el potencial impacto económico para las comunidades locales, así como los potenciales beneficios de conservación para ciertas especies.

El primer capítulo tiene como objetivo identificar los desafíos de la industria del buceo con tiburones en los archipiélagos macaronésicos basados en el análisis de las actividades relacionadas con sus poblaciones en el contexto regional, especialmente la pesca y el turismo, y se presentan las perspectivas y oportunidades para la expansión potencial de este mercado. Combinando una revisión de la literatura con entrevistas con operadores de buceo que ofrecen encuentros con tiburones en los archipiélagos macaronésicos, se brinda una descripción general de los desafíos y el potencial de conservación del turismo de buceo con tiburones para estos territorios insulares.

Este primer capítulo muestra que el buceo con tiburones tiene potencial para expandirse en la región macaronésica principalmente por la presencia regular de especies de tiburones importantes para el turismo y al crecimiento de la industria del buceo en los archipiélagos. Sin embargo, se indica que la presión de la pesca industrial europea en las poblaciones de tiburones oceánicos, junto con la presión del sector pesquero artesanal y recreativo no regulado en las poblaciones de tiburones costeros en las Islas Canarias y Cabo Verde, puede poner en peligro la sostenibilidad de la industria del buceo con tiburones. No obstante, los beneficios económicos para las comunidades locales producidos directa e indirectamente por el turismo

de buceo con tiburones sugieren potenciales beneficios locales, fomentando así una mayor conservación de los tiburones en la Macaronesia.

Este primer capítulo confirma las premisas iniciales del investigador sobre el potencial que existe en los archipiélagos de la Macaronesia para el desarrollo del turismo de buceo con tiburones, así como sus principales amenazas. Además, se reconoce a las Islas Azores como el único archipiélago macaronésico que posee una industria especializada en el buceo con tiburones. Mientras que, en Canarias y Cabo Verde, los encuentros con tiburones son considerados casuales durante las operaciones de buceo recreativo. En el caso del archipiélago de Madeira no se registran encuentros con tiburones en este tipo de operaciones.

En vista de estos hallazgos, el siguiente capitulo se enfoca en estimar la contribución económica regional de la industria del buceo con tiburones en las Islas Azores. Este estudio de valoración se realiza principalmente en función del gasto de los turistas de buceo y las cifras de negocio de las empresas de buceo. Además, se evalúa su potencial para financiar estrategias de conservación de tiburones a través de la disposición a pagar de los turistas de buceo ("Willingness to pay"). Se ofrece así un análisis estandarizado y sólido del impacto socioeconómico de la industria del buceo con tiburones en el archipiélago azoriano utilizando datos de encuestas de turistas de buceo y operadores de buceo locales y se proporciona una evaluación sobre el potencial del turismo de buceo con tiburones que sirva como una fuente de financiación para el establecimiento de un área marina protegida (MPA) para tiburones.

Se estima que la industria aún emergente del buceo con tiburones en las Islas Azores produce cerca de 1 millón de euros al año y podría generar 100 000 euros adicionales para la implementación y manejo de un área marina protegida (MPA) para tiburones en los sitios de buceo. Se considera que esta industria tiene potencial para expandirse en todo el archipiélago macaronésico, aumentando así los ingresos comerciales, y el número de puestos de trabajo e ingresos para las comunidades locales de Azores, promoviendo potencialmente la conservación y el uso sostenible de las poblaciones de tiburones oceánicos. Sin embargo, para que la expansión de esta industria contribuya sólidamente a la economía del archipiélago se sugiere un fortalecimiento concomitante de la regulación de la industria y el apoyo del gobierno para proteger las empresas y las inversiones. Se considera que esto podría obtenerse parcialmente a través de la mejora en la gestión pesquera, la implementación de un área marina protegida funcional y su correcto manejo.

El segundo capítulo no solamente muestra el potencial económico y de conservación del buceo con tiburones en las Islas Azores sino en toda la región macaronésica por los atributos similares que se describen en el primer capítulo. Sin embargo, Azores es una industria joven que recién está posicionándose como un destino turístico internacional para el buceo con tiburones por lo cual se decidió profundizar la investigación en el siguiente capitulo y realizar una comparación de los atributos potenciales para el buceo con tiburones en la Macaronesia con aquellos que poseen destinos turísticos maduros de esta creciente industria mundial.

Así, el tercer capítulo abarca un análisis global de todos los sitios de buceo con tiburones existentes en el mundo, enfocándose principalmente en los atributos que tienen en común. Esta evaluación permitió identificar y estimar la importancia de cada atributo para el desarrollo del buceo con tiburones de manera general. Luego, se propuso un modelo conceptual usando una técnica de clasificación de combinación lineal ponderada que permite realizar una toma de decisiones de atributos múltiples para calcular el valor potencial de buceo con tiburones (SDPV) de los sitios existentes. Finalmente, se aplica este modelo para identificar y evaluar sitios potenciales para el desarrollo del turismo de buceo con tiburones en las Islas Canarias.

Las Islas Canarias son un destino turístico muy popular para buceadores en Europa y se estima que posee la industria de buceo más desarrollada entre los archipiélagos de la Macaronesia (Gonzáles-Mantilla et al., 2021). En 2019 se identificaron 145 centros de buceo distribuidos por el archipiélago canario, de los cuales 108 ofrecían encuentros oportunistas con tiburones (Gonzáles-Mantilla et al., 2021). Si bien los tiburones ángel o angelote (*Squatina squatina*) son una de las especies más comunes en estos encuentros (Baker et al., 2016); en general, se sabe poco sobre el potencial del turismo de buceo con tiburones en el archipiélago. Es por ello que se escogió aplicar el modelo conceptual propuesto en las Islas Canarias, utilizando información obtenida a través de una extensa revisión de la literatura y entrevistas semiestructuradas con actores clave del sector turístico, académico, gubernamental y no gubernamental en el archipiélago.

De esta manera, el tercer capítulo muestra una descripción general de las perspectivas y oportunidades para el desarrollo potencial del turismo de buceo con tiburones en las Islas Canarias. Se identifican 24 sitios potenciales para el desarrollo del turismo de buceo con tiburones en el archipiélago canario de intermedio a alto potencial, distribuidos en las islas de El Hierro, Tenerife, Gran Canaria, Fuerteventura, Lanzarote y La Graciosa. Así, el turismo de buceo con tiburones se presenta como una alternativa económica potencial para integrarse en la industria del turismo marino canario, contribuyendo a la diversificación turística, al aumento de ingresos para las comunidades locales y al uso sostenible de sus recursos marinos.

Conclusiones

Las principales conclusiones del primer capítulo son:

El turismo de buceo con tiburones se considera una alternativa potencialmente sostenible de uso no consuntivo de ciertas especies de tiburones. Esta industria, que puede generar beneficios económicos para comunidades en diferentes partes del mundo, podría expandirse en los archipiélagos macaronésicos. Sin embargo, las principales especies objetivo de la industria del buceo actual también están amenazadas por la pesca comercial y recreativa. En particular, las especies pelágicas y migratorias se solapan con la pesca industrial española y portuguesa en todas las aguas macaronésicas, mientras que las especies costeras están siendo explotadas por la pesca recreativa y artesanal en las Islas Canarias y Cabo Verde. Aunque puede haber algunas operaciones pequeñas que pueden persistir a nivel local, el desarrollo de una industria sólida que pueda proporcionar incentivos a los pescadores locales para apoyar las actividades de buceo requiere establecer una política regional para proteger a los tiburones. Aumentar la conciencia pública sobre la importancia de los tiburones para la salud de los océanos y, lo que es más importante, difundir los beneficios ecológicos y económicos de las operaciones de buceo con tiburones a las autoridades locales de cada archipiélago es la primera etapa de este proceso. También es necesario reforzar la gestión y el control efectivo de las capturas de tiburones (y pesquerías en general) por parte de las flotas locales y extranjeras que operan en las aguas macaronésicas, junto con la creación de áreas protegidas a gran escala en la región.

Los tiburones están ampliamente distribuidos en los océanos del mundo y, por lo tanto, el turismo de buceo con tiburones tiene un gran potencial de expansión. Para aquellos lugares que comparten una conectividad regional, la Macaronesia podría proporcionar un estudio de caso comparable, ya que existen diferentes niveles de desarrollo industrial entre los archipiélagos. Sin embargo, los beneficios potenciales reconocidos del turismo de buceo con tiburones no son directamente aplicables a todos los destinos costeros; por lo tanto, una evaluación previa de los beneficios potenciales que pueden resultar del establecimiento de una

industria de buceo con tiburones en lugares específicos es esencial para lograr objetivos sostenibles y socioeconómicos.

Las principales conclusiones del segundo capítulo son:

Se estimó el valor económico de la industria del turismo de buceo con tiburones dirigido a especies pelágicas u oceánicas en las Islas Azores y el potencial de generación de ingresos para la conservación de estas especies. A pesar de ser uno de los grupos de tiburones más extendidos en el mundo, las especies enfocadas aquí, tiburón azul (*Prionace glauca*) y marrajo de aleta corta (*Isurus oxyrinchus*), han estado modestamente representadas entre las operaciones de turismo de buceo con tiburones a nivel mundial (más del 10%, Gallagher & Hammerschlag, 2011), y los hallazgos de esta investigación contribuyen a una mejor comprensión de las posibles dimensiones económicas de este mercado emergente en el Atlántico Medio. El análisis de valoración contingente basado en la encuesta de disposición a pagar muestra que el turismo de buceo con tiburones de las Islas Azores podría ayudar a obtener recursos financieros para la implementación de un área marina protegida (MPA) para tiburones. Sin embargo, esta industria necesita expandirse para representar un fuerte contribuyente de resultados económicos para la comunidad local y para apoyar estrategias sólidas de conservación.

Las posibilidades de crecimiento de la industria del buceo con tiburones de las Azores dependen principalmente de atraer un mayor número de turistas a la región, en particular buceadores dedicados al buceo con tiburones. Se necesita una mayor concientización entre las autoridades locales sobre los beneficios económicos de esta industria potencialmente sostenible, con el objetivo de mejorar las estrategias de marketing, aumentar el apoyo a los centros de buceo locales para explorar este mercado e integrar a más trabajadores locales de la comunidad de las Islas Azores en la industria del buceo con tiburones.

Las principales conclusiones del tercer capítulo son:

Se propone un nuevo modelo para identificar y evaluar nuevos sitios potenciales para el desarrollo del turismo de buceo con tiburones en función de un análisis global de sus atributos más comunes en los sitios de buceo existentes. El enfoque tiene como objetivo contribuir a una mejor comprensión de los atributos necesarios para evaluar el potencial del turismo de buceo con tiburones en cualquier sitio potencial de buceo con tiburones en el mundo. El análisis global de los sitios actuales de buceo con tiburones ha mostrado principalmente la expansión de la industria global de esta industria en la última década. Además, este análisis también tiene como objetivo servir como una base de datos global para futuras investigaciones sobre las ciencias de los tiburones.

Las Islas Canarias han mostrado signos de alto potencial para el desarrollo del turismo de buceo con tiburones; sin embargo, la presente investigación es una primera imagen de una extensa evaluación del potencial turístico de esta industria. Este estudio es el primero en mapear y contextualizar sitios potenciales para el desarrollo del turismo de buceo con tiburones en las Islas Canarias y podría servir potencialmente a las autoridades gubernamentales como una guía para planificar el desarrollo del turismo de buceo con tiburones en el archipiélago.

Limitaciones y futuras líneas de investigación

El presente trabajo contribuye a cubrir un vacío académico sobre el turismo de buceo con tiburones, y sobre tiburones en general, en la región Macaronesia, contextualizando y describiendo sus potenciales atributos para el desarrollo de esta industria, analizando el potencial impacto económico para las comunidades locales, así como los potenciales beneficios de conservación para ciertas especies. Sin embargo, esta investigación presenta limitaciones principalmente debido a la escasa información previa sobre las poblaciones de tiburones en términos biológicos y ecológicos, y de su uso consuntivo en la Macaronesia, como por ejemplo los datos históricos de pesca de tiburones en las Islas Canarias. Además, la presente investigación no pudo abordar un estudio del potencial del buceo con tiburones que incluyera datos primarios ofrecidos por turistas en Canarias y en Cabo Verde principalmente debido a las restricciones provocadas por la pandemia COVID-19 entre los años 2020-2021.

Otro aspecto que podría considerarse una limitación es la muestra representativa del gasto de turistas de buceo en las Islas Azores. Si bien las encuestas fueron realizadas entre finales de Agosto e inicio de Octubre de 2019, la temporada de buceo con tiburones comenzaba a finales de Junio. Además, por razones logísticas las operaciones terminaron a finales de Setiembre por la llegada del Huracán Lorenzo, por lo cual la muestra de turistas encuestados representó a un tercio de la temporada total.

Finalmente, en la investigación realizada en Canarias se había previsto inicialmente entrevistar a representantes de las asociaciones de pescadores locales también conocidos como "Cofradías" con el objetivo de obtener una información de primera mano sobre la pesca de tiburones en el archipiélago canario. Sin embargo, por razones logísticas no se pudo contactar a estos actores que podrían haber aportado información importante para este trabajo como se ha observado en otras investigaciones (Jabado et al., 2015; García-Rodríguez & Sosa-Nishizaki, 2020; Mason et al., 2020; Almojil, 2021).

La presente investigación, a pesar de sus limitaciones, ha cumplido los objetivos propuestos inicialmente, no obstante, debe ser considerada como el punto de partida para futuras investigaciones sobre el estudio de los tiburones en la región Macaronesia. En primer lugar, se recomienda realizar una investigación más profunda sobre el potencial de beneficio a largo plazo de las actividades de buceo con tiburones en sus archipiélagos. Para lograr esto, las lagunas de conocimiento más importantes que deben llenarse son los datos sobre la abundancia y distribución de las poblaciones de tiburones en las aguas macaronésicas, las valoraciones socioeconómicas de la industria potencial de buceo con tiburones en cada archipiélago, los datos actualizados sobre las pesquerías de tiburones del Noreste Atlántico al Océano Atlántico Centro-Este, y evaluaciones de las percepciones de las comunidades locales (ej.: pescadores, etc.) y la inclusión social en la industria del turismo de buceo con tiburones.

También se recomienda realizar una evaluación del potencial del buceo con tiburones en Madeira. Si bien no fue tomado en cuenta dentro del análisis elaborado en el primer capítulo dado que los operadores de buceo locales no reportaron encuentros con tiburones, los datos obtenidos en la revisión bibliográfica consideran que hay abundancia de especies objetivo para el turismo en su territorio. Con relación a Canarias y Cabo Verde, son necesarios futuros estudios sobre la percepción y disposición a pagar de los turistas sobre las posibles actividades de buceo con tiburones. Además, considerando el mercado potencial de las actividades de buceo recreativo en ambos archipiélagos, se sugiere una mayor investigación sobre la valoración socioeconómica general de su industria de buceo.

Referencias

Almojil, D. (2021). Local ecological knowledge of fisheries charts decline of sharks in data-poor regions. Marine Policy, 132, 104638.

Brunnschweiler, J. M., & Ward-Paige, C. A. (2014). Shark fishing and tourism. Oryx, 48(4), 486-487.

Cater, C. (2007). Perceptions of and interactions with marine environments: Diving attractions from great whites to pygmy seahorses. In New frontiers in marine tourism (pp. 71-86). Routledge.

Catlin, J., Hughes, M., Jones, T., Jones, R., & Campbell, R. (2013). Valuing individual animals through tourism: Science or speculation?. Biological conservation, 157, 93-98.

Cazabon-Mannette, M., Schuhmann, P. W., Hailey, A., & Horrocks, J. (2017). Estimates of the non-market value of sea turtles in Tobago using stated preference techniques. Journal of environmental management, 192, 281-291.

Cisneros-Montemayor, A. M., Barnes-Mauthe, M., Al-Abdulrazzak, D., Navarro-Holm, E., & Sumaila, U. R. (2013). Global economic value of shark ecotourism: implications for conservation. Oryx, 47(3), 381-388.

Clua, E., Buray, N., Legendre, P., Mourier, J., & Planes, S. (2011). Business partner or simple catch? The economic value of the sicklefin lemon shark in French Polynesia. Marine and Freshwater Research, 62(6), 764-770.

DeLorenzo, J., & Techera, E. J. (2019). Ensuring good governance of marine wildlife tourism: a case study of ray-based tourism at Hamelin Bay, Western Australia. Asia Pacific Journal of Tourism Research, 24(2), 121-135.

Dent, F., & Clarke, S. (2015). State of the global market for shark products. FAO Fisheries and Aquaculture technical paper, (590), I.

Dicken, M. L., & Hosking, S. G. (2009). Socio-economic aspects of the tiger shark diving industry within the Aliwal Shoal Marine Protected Area, South Africa. African Journal of Marine Science, 31(2), 227-232.

Dulvy, N. K., Fowler, S. L., Musick, J. A., Cavanagh, R. D., Kyne, P. M., Harrison, L. R., ... & White, W. T. (2014). Extinction risk and conservation of the world's sharks and rays. elife, 3, e00590.

Dulvy, N. K., Simpfendorfer, C. A., Davidson, L. N., Fordham, S. V., Bräutigam, A., Sant, G., & Welch, D. J. (2017). Challenges and priorities in shark and ray conservation. Current Biology, 27(11), R565-R572.

Ferretti, F., Jacoby, D. M., Pfleger, M. O., White, T. D., Dent, F., Micheli, F., ... & Block, B. A. (2020). Shark fin trade bans and sustainable shark fisheries. Conservation Letters, 13(3), e12708.

Gallagher, A. J., & Hammerschlag, N. (2011). Global shark currency: the distribution, frequency, and economic value of shark ecotourism. Current Issues in Tourism, 14(8), 797-812.

Gallagher, A. J., Vianna, G. M., Papastamatiou, Y. P., Macdonald, C., Guttridge, T. L., & Hammerschlag, N. (2015). Biological effects, conservation potential, and research priorities of shark diving tourism. Biological Conservation, 184, 365-379.

García-Rodríguez, E., & Sosa-Nishizaki, O. (2020). Artisanal fishing activities and their documented interactions with juvenile white sharks inside a nursery area. Aquatic Conservation: Marine and Freshwater Ecosystems, 30(5), 903-914.

Gibson, C., Valenti, S. V., Fowler, S. L., & Fordham, S. V. (2008). The conservation status of Northeast Atlantic chondrichthyans. Report of the IUCN Shark Specialist Group Northeast Atlantic Red List Workshop; p. 76.

Haas, A. R., Fedler, T., & Brooks, E. J. (2017). The contemporary economic value of elasmobranchs in The Bahamas: Reaping the rewards of 25 years of stewardship and conservation. Biological conservation, 207, 55-63.

Hernández Martín, R., Antonova, N., Celis Sosa, D., Fernández Hernández, C., González Hernández, M., Herrera Priano, F. Á., ... & Simancas Cruz, M. R. (2021). Tourism Observatory of the Canary Islands.

Higginbottom, K., & Scott, N. (2008). Strategic planning of wildlife tourism in Australia. Journal of Ecotourism, 7(2-3), 102-115.

Higginbottom, K. (2004). Wildlife tourism. Altona: Common Ground.

Higham, J. E., & Lück, M. (Eds.). (2007). Marine wildlife and tourism management: Insights from the natural and social sciences. CABI.

Huveneers, C., & Robbins, W. (2014). Species at the intersection. Sharks: conservation, governance and management, 236-260.

Huveneers, C., Meekan, M. G., Apps, K., Ferreira, L. C., Pannell, D., & Vianna, G. (2017). The economic value of shark-diving tourism in Australia. Reviews in Fish Biology and Fisheries, 27(3), 665-680.

Inman, A., Brooker, E., Dolman, S., McCann, R., & Wilson, A. M. W. (2016). The use of marine wildlife-watching codes and their role in managing activities within marine protected areas in Scotland. Ocean & coastal management, 132, 132-142.

IUCN-International Union for Conservation of Nature. (2013). The IUCN Red List of Threatened Species. Version 2013.2.

Jabado, R. W., Al Ghais, S. M., Hamza, W., & Henderson, A. C. (2015). The shark fishery in the United Arab Emirates: an interview based approach to assess the status of sharks. Aquatic Conservation: Marine and Freshwater Ecosystems, 25(6), 800-816.

Lück, M., & Orams, M. B. (2020). Marine Wildlife Tourism and Safety. Tourism in Marine Environments, 15(3-4), 123-126.

Mason, J. G., Alfaro-Shigueto, J., Mangel, J. C., Crowder, L. B., & Ardoin, N. M. (2020). Fishers' solutions for hammerhead shark conservation in Peru. Biological Conservation, 243, 108460.

McIntosh, R. R., Kirkwood, R., Sutherland, D. R., & Dann, P. (2015). Drivers and annual estimates of marine wildlife entanglement rates: a long-term case study with Australian fur seals. Marine pollution bulletin, 101(2), 716-725.

Mieras, P. A., Harvey-Clark, C., Bear, M., Hodgin, G., & Hodgin, B. (2017). The economy of shark conservation in the Northeast Pacific: The role of ecotourism and citizen science. In Advances in marine biology (Vol. 78, pp. 121-153). Academic Press.

MMC (2019). The Economics of Marine Mammals. Published by the Marine Mammal Commission.

Mustika, P. L. K., Ichsan, M., & Booth, H. (2020). The economic value of shark and ray tourism in Indonesia and its role in delivering conservation outcomes. Frontiers in Marine Science, 261.

Newsome, D., & Rodger, K. (2013). Feeding of wildlife: An acceptable practice in ecotourism?. International handbook on ecotourism.

Nieto, A., Ralph, G.M., Comeros-Raynal, M.T., Kemp, J., García Criado, M., Allen, D.J., Dulvy, N.K., Walls, R.H.L., Russell, B., Pollard, D., García, S., Craig, M., Collette, B.B., Pollom, R., Biscoito, M., Labbish Chao, N., Abella, A., Afonso, P., Álvarez, H., Carpenter, K.E., Clò, S., Cook, R., Costa, M.J., Delgado, J., Dureuil, M., Ellis, J.R., Farrell, E.D., Fernandes, P., Florin, A-B., Fordham, S., Fowler, S., Gil de Sola, L., Gil Herrera, J., Goodpaster, A., Harvey, M., Heessen, H., Herler, J., Jung, A., Karmovskaya, E., Keskin, C., Knudsen, S.W., Kobyliansky, S., Kovačić, M., Lawson, J.M., Lorance, P., McCully Phillips, S., Munroe, T., Nedreaas, K., Nielsen, J., Papaconstantinou, C., Polidoro, B., Pollock, C.M., Rijnsdorp, A.D., Sayer, C., Scott, J., Serena, F., Smith-Vaniz, W.F., Soldo, A., Stump, E., & Williams, J.T. (2015). European Red List of marine fishes. Luxembourg: Publications Office of the European Union.

Patroni, J., Simpson, G., & Newsome, D. (2018). Feeding wild fish for tourism—A systematic quantitative literature review of impacts and management. International Journal of Tourism Research, 20(3), 286-298.

Pauly, D., Christensen, V., Guenette, S., Pitcher, T., Sumaila, R., Walters, C., Watson, R., & Zeller, D. (2002). Towards sustainability in world fisheries. Nature. 418. 689-95. 10.1038/nature01017.

Pires, N. M., Garla, R. C., & Carvalho, A. R. (2016). The economic role of sharks in a major ecotourism archipelago in the western South Atlantic. Marine Policy, 72, 31-39.

Rodger, K., Smith, A., Newsome, D., & Moore, S. A. (2011). Developing and testing an assessment framework to guide the sustainability of the marine wildlife tourism industry. Journal of Ecotourism, 10(2), 149-164.

Rodger, K., Smith, A., Davis, C., Newsome, D., & Patterson, P. (2010). A framework to guide the sustainability of wildlife tourism operations: examples of marine wildlife tourism in Western Australia.

Simpfendorfer, C. A., & Dulvy, N. K. (2017). Bright spots of sustainable shark fishing. Current Biology, 27(3), R97-R98.

Sutcliffe, S. R., & Barnes, M. L. (2018). The role of shark ecotourism in conservation behaviour: Evidence from Hawaii. Marine Policy, 97, 27-33.

Tapper, R. (2006). Wildlife watching and tourism: a study on the benefits and risks of a fast growing tourism activity and its impacts on species. UNEP/Earthprint.

Topelko, K. N., & Dearden, P. (2005). The shark watching industry and its potential contribution to shark conservation. Journal of Ecotourism, 4(2), 108-128.

Torres, P., Bolhão, N., da Cunha, R. T., Vieira, J. A. C., & dos Santos Rodrigues, A. (2017). Dead or alive: The growing importance of shark diving in the Mid-Atlantic region. Journal for Nature Conservation, 36, 20-28.

Vianna, G. M. S., Meeuwig, J. J., Pannell, D., Sykes, H., & Meekan, M. G. (2011). The socioeconomic value of the shark-diving industry in Fiji. Perth: University of Western Australia. 26p.

Vianna, G. M., Meekan, M. G., Pannell, D. J., Marsh, S. P., & Meeuwig, J. J. (2012). Socio-economic value and community benefits from shark-diving tourism in Palau: a sustainable use of reef shark populations. Biological Conservation, 145(1), 267-277.

Vianna, G. M., Meekan, M. G., Rogers, A. A., Kragt, M. E., Alin, J. M., & Zimmerhackel, J. S. (2018). Shark-diving tourism as a financing mechanism for shark conservation strategies in Malaysia. Marine Policy, 94, 220-226.

Worm, B., Davis, B., Kettemer, L., Ward-Paige, C. A., Chapman, D., Heithaus, M. R., ... & Gruber, S. H. (2013). Global catches, exploitation rates, and rebuilding options for sharks. Marine Policy, 40, 194-204.

Zimmerhackel, J. S., Kragt, M. E., Rogers, A. A., Ali, K., & Meekan, M. G. (2019). Evidence of increased economic benefits from shark-diving tourism in the Maldives. Marine Policy, 100, 21-26.

INTRODUCTION

The present dissertation aims to contribute to a better understanding of the potential sustainable use of sharks through diving tourism as opposed to the fishing exploitation of their populations in the Macaronesian archipelagos. This work is divided into 3 chapters: the first that addresses in a general way the challenges and opportunities to develop this activity throughout the study area; the second estimates the economic impact of the only existing shark-diving tourism industry in Macaronesia; and the third that proposes a conceptual model that allows calculating the potential for development of this activity in any diving site in the world and that is applied as a case study in potential diving sites in the Canary archipelago. The first chapter serves as an introduction to shark-related activities in the Macaronesian region such as fishing, conservation, and tourism. The second chapter delves into the economic value of shark-diving tourism in the Azores Islands and its conservation potential, which serves as a reference for potential development of this industry in the rest of the Macaronesian archipelagos. Finally, the third aims to identify and evaluate potential areas and locations for shark-diving tourism in the Canary Islands. This research allows us to understand that the general state of overfishing and severe declines in shark populations in the Macaronesian region will inevitably result in a decline in catches in the near future, which could also reduce the economic value of shark fishing. Therefore, alternative non-consumptive uses of shark populations, such as diving tourism, should be preferred from a socioeconomic and conservation perspective and have been shown to represent a potentially attractive strategy in the Macaronesian archipelagos.

Introduction

In recent decades, the observation and interaction with coastal and marine fauna in their natural habitat has strongly increased, becoming one of the sectors with greatest potential in the tourism industry (Tapper, 2006; Patroni et al., 2018). Globally, wildlife tourism is estimated to be valued at US$45 billion, with an annual growth rate of 10% (Newsome & Rodger, 2013), while the marine wildlife tourism industry is estimated to generate more than $2 billion per year, attracting 13 million tourists and supporting 13,000 jobs (MMC, 2019). Its growing tourist demand can be partially attributed to the greater promotion and knowledge of marine life from nature documentaries and reports in the mass media (Rodger et al., 2011). Along with the growth of these activities, their research has also increased, focusing largely on potential and actual impacts on target species, visitor experiences and satisfaction, as well as education and interpretation on commercial tours (Lück & Orams, 2020).

Interactions with marine wildlife may be facilitated by commercial operators, intentionally sought by private individuals and groups, or incidental during other marine activities such as diving, swimming, surfing, kayaking, etc. The target species vary from marine mammals to reptiles, birds, fish, among others, and occurs in different and varied coastal destinations around the world, such as Australia, the United States, Sri Lanka, Alaska, South Africa or Scotland. For example, marine wildlife tourism in Australia includes whale watching, turtle watching, manta ray feeding, sea lion watching, and swimming interactions with dolphins and whale sharks (*Rhincodon typus*), operating in many locations across the country (Higginbottom & Scott , 2008; Rodger et al., 2010; McIntosh et al., 2015; DeLorenzo & Techera, 2019). Whereas, in Scotland, for example, marine wildlife tourism activities are mainly focused on the observation of dolphins, seals, whales and more recently swimming interactions with basking sharks (*Cetorhinus maximus*, Inman et al., 2016).

Indeed, a significant sector of wildlife tourism focuses on viewing marine megafauna (Higham & Lück, 2007), and sharks are rapidly becoming major tourist attractions (Huveneers &

Robbins, 2014). This type of non-consumptive use of sharks, first developed in the late 20th century (Topelko & Dearden, 2005), has been growing in popularity and is now a global phenomenon (Gallagher & Hammerschlag, 2011). In recent years, sharks have become major attractions at many dive sites around the world, contributing to local, regional and national economies in North America, Central and South America, Europe, the Wider Caribbean, Oceania , North Africa and the Middle East, Asia and Indonesia. and Southern and Eastern Africa (Topelko & Dearden, 2005; Gallagher & Hammerschlag, 2011; Vianna et al., 2011; Haas et al., 2017; Huveneers et al., 2017; Mieras et al., 2017; Zimmerhackel et al., 2019). The observation of these animals in their natural habitat, either from boats or underwater with snorkeling or diving equipment, is a niche in the rapidly developing marine tourism market (Cater, 2007). In addition to producing positive changes in tourists' conservation knowledge, attitudes, and behaviors (Gallagher et al., 2015; Sutcliffe et al., 2018) and making significant contributions to national economies, revenues from this industry are responsible for livelihoods of local communities, and support conservation and management strategies (Vianna et al., 2012, 2018).

Shark-diving tourism has also seen an increase in academic attention. A literature review by Gallagher et al. (2015) found that, up to 2014, 47 original research articles focusing on some aspect of shark-diving tourism industry had been published, with 47% of these studies consisting of socioeconomic analyzes conducted at many scales. These studies generally concluded that, where shark diving tourism is viable, the economic benefits of shark conservation are potentially greater than those that can be achieved by fisheries exploiting the same resources (Clua et al., 2011, Vianna et al., 2011 ; Vianna et al., 2012; Cisneros-Montemayor et al., 2013). For example, Cisneros-Montemayor et al. (2013) estimated the global value of shark-diving industry to be around US$314 million in 2011, directly supporting around 10 000 jobs. While the accuracy of these estimates has been a source of debate (see Brunnschweiler & Ward-Paige, 2014), many studies have shown that shark-based tourism has driven changes in the socioeconomic importance of sharks from a fishery product to a most valuable non-consumptive use product in many tourist destinations around the world (Gallagher et al., 2015).

Economic valuations have undoubtedly played an increasingly important role in shaping policy decisions regarding the conservation and management of wildlife, including sharks (Cazabon-Mannette et al., 2017; Gallagher et al., 2015). Although there are no reliable global measures of the economic impact of wildlife tourism (Higginbottom, 2004), a variety of methods have been used to estimate the total economic impact of this industry, from considering the value added of production to the volume from income from tour or access tickets to the use of intersectional macroeconomic impact models through input and output analysis (Catlin et al., 2013). In the case of shark-diving tourism, socioeconomic studies have been conducted at many scales, providing an overview of the contribution of this industry to regional and national economies (eg, Dicken & Hosking, 2009; Clua et al. ., 2011; Vianna et al. al., 2011; Gallagher & Hammerschlag, 2011; Vianna et al., 2012; Cisneros-Montemayor et al., 2013; Pires et al., 2016; Torres et al., 2017; Haas et al., 2017; Huveneers et al. al., 2017; Mieras et al., 2017; Zimmerhackel et al., 2019). Economic valuations and evaluations of this sector are well established in the scientific literature; however, inconsistencies in methods between studies and time lags among estimates may limit the ability to compare and combine results to provide global estimates for the shark-diving industry (Gallagher et al., 2015).

In more recent years, standardized valuation methods have been used in several countries around the world. These valuation studies have quantified the direct and indirect expenses of the participants involved in shark-diving activities, quantifying similar metrics to assess the economic impact of this industry and the benefits for the destination where the activity is

established (eg, Vianna et al., 2011; Vianna et al., 2012; Huveneers et al., 2017; Haas et al., 2017; Vianna et al., 2018; Mustika et al., 2020). Following this line, the present work aims to evaluate the potential socioeconomic impact of the shark-diving tourism industry in the archipelagos of Macaronesia. This biogeographic region that compounds the Portuguese islands of Azores and Madeira, the Canary Islands in Spain and the Cape Verde Islands, has one of the highest rates of marine biodiversity in the Northeast Atlantic and is a transitory zone for migratory species such as turtles, cetaceans and sharks (Nieto et al., 2015). This work also aims to assess the potential expansion of the shark-diving tourism industry in the Macaronesian region and the potential conservation benefits for the populations of the target species found in their territories.

Justification of the subject analyzed

Sharks play a fundamental role in marine ecosystems. As top predators in the food web, they maintain the trophic balance of the oceans and their presence is an indicator of a healthy ecosystem. However, these predators have particular physiological characteristics such as slow growth and low reproduction, which makes them vulnerable to overfishing. Historically, sharks were generally considered a bycatch in fisheries targeting other more valuable species (Dulvy et al., 2017); however, in recent decades the global demand for shark products has progressively increased, shifting shark fisheries from bycatch to target species in many fisheries (Dent & Clarke, 2015).

Sharks are caught by fishing fleets around the world, with an estimate of up to 100 million individuals per year (Worm et al., 2013). In 2015, the global market for shark products was estimated to generate approximately USD$1 billion traded annually (Dent & Clarke, 2015). However, poor regulation of shark fisheries, including the common practice of finning on the high seas (Chen & Phipps, 2002; Lehr, 2015; Dulvy et al., 2017), has led to precipitous global declines in many shark populations (Worm et al., 2013; Dulvy et al., 2014). Due to overfishing, sharks are now accepted worldwide as a priority conservation group (Dulvy et al., 2014), with 20% of the nearly 500 known shark species under threat of extinction, according to the Red List of the International Union for Conservation of Nature – IUCN (IUCN, 2013).

While numerous fisheries management tools are used to prevent shark overexploitation, effective implementation of these approaches is restricted to a few species and in developing countries with strong fisheries management systems in place (Simpendorfer & Dulvy, 2017; Ferretti et al. al., 2020). Unfortunately, effective fisheries management is the exception, not the rule, for most regions of the world (Pauly et al., 2002) and, in light of these challenges, new economic perspectives are now opening up that may allow a more sustainable use of sharks such as shark-diving tourism industry.

The identification and evaluation of new potential sites for the development of shark-diving tourism is strongly recommended in the general literature (Topelko & Dearden, 2005; Cisneros-Montemayor et al., 2013), particularly in those regions experiencing a significant decline of shark populations due to overfishing, such as in the Northeast Atlantic (Gibson et al., 2008). However, only about 10% of published scientific studies on shark-diving tourism have focused on the Atlantic Ocean (Gallagher et al., 2015), despite the high number of shark-diving operations in this region, (Gallagher & Hammerschlag, 2011) and to date no study has focused on the Northeast Atlantic in particular, including the Macaronesia region.

Objectives and summary of each chapter

The main objective of this research is to contribute to a better understanding of the sustainable use of sharks through the development of shark-diving tourism in contrast to the fishing exploitation of their populations in the Macaronesian archipelagos. First, a preliminary assessment of the current situation of human use of shark populations in the Macaronesian region was carried out, where some evidence of their tourism potential was identified, as well as the main threats to certain species. Then, using research and successful case studies in the world on tourist use of sharks as a sustainable alternative to fishing as a basis, it was proposed to analyze the possibilities of developing shark-diving tourism in the Macaronesian archipelagos. In this way, the present work attempts to fill the research gap on shark-diving tourism, and on sharks in general, in this region of the Northeast Atlantic, contextualizing and describing the potential economic impact for local communities, as well as the potential conservation benefits for certain species.

The first chapter aims to identify the challenges of the shark-diving industry in the Macaronesian archipelagos based on the analysis of the activities related to their populations in the regional context, especially fishing and tourism, presenting the perspectives and opportunities for the potential expansion of this market. Combining a literature review with interviews with dive operators offering shark encounters in the Macaronesian archipelagos, an overview of the challenges and conservation potential of shark diving tourism for these island territories is provided.

This first chapter shows that shark-diving tourism has the potential to expand in the Macaronesian region mainly due to the regular presence of important shark species for tourism and the growth of the diving industry in the archipelagos. However, it is indicated that the pressure of European industrial fishing on oceanic shark populations, together with the pressure of the unregulated artisanal and recreational fishing sector on coastal shark populations in the Canary Islands and Cape Verde, may endanger the sustainability of the shark-diving industry. However, the economic benefits to local communities produced directly and indirectly by shark-diving tourism suggest potential local benefits, thus fostering greater conservation of sharks in Macaronesia.

This first chapter confirms the initial premises of the researcher about the potential that exists in the Macaronesian archipelagos for the development of shark-diving tourism, as well as its main threats. The Azores Islands are recognized as the only Macaronesian archipelago that has an industry specialized in diving with sharks. While, in the Canary Islands and Cape Verde, encounters with sharks are considered casual during recreational diving operations. In the case of the Madeira archipelago, no encounters with sharks have been recorded in this type of operation.

In view of these findings, the following chapter focuses on estimating the regional economic contribution of the shark-diving industry in the Azores Islands. This valuation study is carried out mainly based on diving tourists' expenses and business figures of diving companies. Furthermore, its potential to finance shark conservation strategies through willingness to pay of diving tourists is evaluated. This provides a standardized and robust analysis of the socioeconomic impact of the shark-diving industry in the Azorean archipelago using survey data from dive tourists and local dive operators and provides an assessment of the potential of shark-diving tourism that could potentially serve as a source of funding for the implementation and management of a marine protected area (MPA) for sharks.

It is estimated that the still emerging industry of shark-diving tourism in the Azores Islands yields near to 1 million euros per year and could generate an additional 100 000 euros for the

implementation and management of a marine protected area (MPA) for sharks around the shark-diving sites. It is considered that this industry has the potential to expand throughout the Macaronesian archipelago, thus increasing commercial income, and the number of jobs and income for local communities in the Azores, potentially promoting the conservation and sustainable use of oceanic shark populations. However, for the expansion of this industry to make a solid contribution to the archipelago's economy, a concomitant strengthening of industry regulation and government support to protect businesses and investments is suggested. It is considered that this could be partially achieved through improved fisheries management, implementation of a functional marine protected area and its proper management.

The second chapter not only shows the economic and conservation potential of diving with sharks in the Azores Islands, but in the entire Macaronesian region due to the similar attributes described in the first chapter. However, Azores is a nascent industry that is beginning to positioning itself as an international tourist destination for shark diving, for which it was decided to deepen the investigation in the next chapter and make a comparison of the potential attributes for shark-diving tourism in Macaronesia with those from mature tourist destinations in this growing global industry.

Thus, the third chapter covers a global analysis of all existing shark-diving sites around the world, focusing mainly on the attributes they have in common. This evaluation aimed to identify and estimate the importance of each attribute for the overall development of shark-diving tourism. Then, a conceptual model was proposed using a weighted linear combination classification technique that enables multi-attribute decision making to estimate shark-diving potential value (SDPV) of existing sites. Finally, this model is applied to identify and evaluate potential sites for the development of shark-diving tourism in the Canary Islands.

The Canary Islands are a very popular tourist destination for divers in Europe and are estimated to have the most developed diving industry among the Macaronesian archipelagos (Gonzáles-Mantilla et al., 2021). In 2019, 145 diving centers distributed throughout the Canary archipelago were identified, of which 108 offered opportunistic encounters with sharks (Gonzáles-Mantilla et al., 2021). Although angel sharks (*Squatina squatina*) are one of the most common species in these encounters (Baker et al., 2016); overall, little is known about the potential for shark-diving tourism in the archipelago. For this reason, the conceptual model proposed is applied in the Canary Islands, using information obtained through an extensive review of the literature and semi-structured interviews with stakeholders from the tourism, academic, governmental and non-governmental sectors in the archipelago.

In this way, the third chapter shows an overview of the perspectives and opportunities for the potential development of shark-diving tourism in the Canary Islands. Twenty-four potential sites are identified for the development of shark-diving tourism in the Canary archipelago with intermediate to high SDPV, distributed in the islands of El Hierro, Tenerife, Gran Canaria, Fuerteventura, Lanzarote and La Graciosa. Thus, shark-diving tourism is presented as a potential economic alternative to integrate into the Canarian marine tourism industry, contributing to tourism diversification, increasing income for local communities and sustainable use of its marine resources.

In summary, this thesis aims to gain a better understanding of shark-diving tourism potential in the Macaronesian archipelagos through a qualitative and quantitative approach. The research techniques applied to gather the information used in this work were a broad literature review, documental analysis and semi-structured questionnaires conducted from 2016 to 2021 in the Azores and, mainly, in the Canary Islands. The analytical technique employed is based

on as statistical analysis (spiked censored interval regression model) and weighted linear combination ranking technique.

In addition to specific conclusions in each chapter, the thesis culminates with some general conclusions. Likewise, this last section includes the main contributions, implications and recommendations. Finally, some limitations and future studies are suggested.

References

Brunnschweiler, J. M., & Ward-Paige, C. A. (2014). Shark fishing and tourism. Oryx, 48(4), 486-487.

Cater, C. (2007). Perceptions of and interactions with marine environments: Diving attractions from great whites to pygmy seahorses. In New frontiers in marine tourism (pp. 71-86). Routledge.

Catlin, J., Hughes, M., Jones, T., Jones, R., & Campbell, R. (2013). Valuing individual animals through tourism: Science or speculation?. Biological conservation, 157, 93-98.

Cazabon-Mannette, M., Schuhmann, P. W., Hailey, A., & Horrocks, J. (2017). Estimates of the non-market value of sea turtles in Tobago using stated preference techniques. Journal of environmental management, 192, 281-291.

Cisneros-Montemayor, A. M., Barnes-Mauthe, M., Al-Abdulrazzak, D., Navarro-Holm, E., & Sumaila, U. R. (2013). Global economic value of shark ecotourism: implications for conservation. Oryx, 47(3), 381-388.

Clua, E., Buray, N., Legendre, P., Mourier, J., & Planes, S. (2011). Business partner or simple catch? The economic value of the sicklefin lemon shark in French Polynesia. Marine and Freshwater Research, 62(6), 764-770.

DeLorenzo, J., & Techera, E. J. (2019). Ensuring good governance of marine wildlife tourism: a case study of ray-based tourism at Hamelin Bay, Western Australia. Asia Pacific Journal of Tourism Research, 24(2), 121-135.

Dent, F., & Clarke, S. (2015). State of the global market for shark products. FAO Fisheries and Aquaculture technical paper, (590), I.

Dicken, M. L., & Hosking, S. G. (2009). Socio-economic aspects of the tiger shark diving industry within the Aliwal Shoal Marine Protected Area, South Africa. African Journal of Marine Science, 31(2), 227-232.

Dulvy, N. K., Fowler, S. L., Musick, J. A., Cavanagh, R. D., Kyne, P. M., Harrison, L. R., ... & White, W. T. (2014). Extinction risk and conservation of the world's sharks and rays. elife, 3, e00590.

Dulvy, N. K., Simpfendorfer, C. A., Davidson, L. N., Fordham, S. V., Bräutigam, A., Sant, G., & Welch, D. J. (2017). Challenges and priorities in shark and ray conservation. Current Biology, 27(11), R565-R572.

Ferretti, F., Jacoby, D. M., Pfleger, M. O., White, T. D., Dent, F., Micheli, F., ... & Block, B. A. (2020). Shark fin trade bans and sustainable shark fisheries. Conservation Letters, 13(3), e12708.

Gallagher, A. J., & Hammerschlag, N. (2011). Global shark currency: the distribution, frequency, and economic value of shark ecotourism. Current Issues in Tourism, 14(8), 797-812.

Gallagher, A. J., Vianna, G. M., Papastamatiou, Y. P., Macdonald, C., Guttridge, T. L., & Hammerschlag, N. (2015). Biological effects, conservation potential, and research priorities of shark diving tourism. Biological Conservation, 184, 365-379.

Gibson, C., Valenti, S. V., Fowler, S. L., & Fordham, S. V. (2008). The conservation status of Northeast Atlantic chondrichthyans. Report of the IUCN Shark Specialist Group Northeast Atlantic Red List Workshop; p. 76.

Haas, A. R., Fedler, T., & Brooks, E. J. (2017). The contemporary economic value of elasmobranchs in The Bahamas: Reaping the rewards of 25 years of stewardship and conservation. Biological conservation, 207, 55-63.

Hernández Martín, R., Antonova, N., Celis Sosa, D., Fernández Hernández, C., González Hernández, M., Herrera Priano, F. Á., ... & Simancas Cruz, M. R. (2021). Tourism Observatory of the Canary Islands.

Higginbottom, K., & Scott, N. (2008). Strategic planning of wildlife tourism in Australia. Journal of Ecotourism, 7(2-3), 102-115.

Higginbottom, K. (2004). Wildlife tourism. Altona: Common Ground.

Higham, J. E., & Lück, M. (Eds.). (2007). Marine wildlife and tourism management: Insights from the natural and social sciences. CABI.

Huveneers, C., & Robbins, W. (2014). Species at the intersection. Sharks: conservation, governance and management, 236-260.

Huveneers, C., Meekan, M. G., Apps, K., Ferreira, L. C., Pannell, D., & Vianna, G. (2017). The economic value of shark-diving tourism in Australia. Reviews in Fish Biology and Fisheries, 27(3), 665-680.

Inman, A., Brooker, E., Dolman, S., McCann, R., & Wilson, A. M. W. (2016). The use of marine wildlife-watching codes and their role in managing activities within marine protected areas in Scotland. Ocean & coastal management, 132, 132-142.

IUCN-International Union for Conservation of Nature. (2013). The IUCN Red List of Threatened Species. Version 2013.2.

Lück, M., & Orams, M. B. (2020). Marine Wildlife Tourism and Safety. Tourism in Marine Environments, 15(3-4), 123-126.

McIntosh, R. R., Kirkwood, R., Sutherland, D. R., & Dann, P. (2015). Drivers and annual estimates of marine wildlife entanglement rates: a long-term case study with Australian fur seals. Marine pollution bulletin, 101(2), 716-725.

Mieras, P. A., Harvey-Clark, C., Bear, M., Hodgin, G., & Hodgin, B. (2017). The economy of shark conservation in the Northeast Pacific: The role of ecotourism and citizen science. In Advances in marine biology (Vol. 78, pp. 121-153). Academic Press.

MMC (2019). The Economics of Marine Mammals. Published by the Marine Mammal Commission.

Mustika, P. L. K., Ichsan, M., & Booth, H. (2020). The economic value of shark and ray tourism in Indonesia and its role in delivering conservation outcomes. Frontiers in Marine Science, 261.

Newsome, D., & Rodger, K. (2013). Feeding of wildlife: An acceptable practice in ecotourism?. International handbook on ecotourism.

Nieto, A., Ralph, G.M., Comeros-Raynal, M.T., Kemp, J., García Criado, M., Allen, D.J., Dulvy, N.K., Walls, R.H.L., Russell, B., Pollard, D., García, S., Craig, M., Collette, B.B., Pollom, R., Biscoito, M., Labbish Chao, N., Abella, A., Afonso, P., Álvarez, H., Carpenter, K.E., Clò, S., Cook, R., Costa, M.J., Delgado, J., Dureuil, M., Ellis, J.R., Farrell, E.D., Fernandes, P., Florin, A-B., Fordham, S., Fowler, S., Gil de Sola, L., Gil Herrera, J., Goodpaster, A., Harvey, M., Heessen, H., Herler, J., Jung, A., Karmovskaya, E., Keskin, C., Knudsen, S.W., Kobyliansky, S., Kovačić, M., Lawson, J.M., Lorance, P., McCully Phillips, S., Munroe, T., Nedreaas, K., Nielsen, J., Papaconstantinou, C., Polidoro, B., Pollock, C.M., Rijnsdorp, A.D., Sayer, C., Scott, J., Serena, F., Smith-Vaniz, W.F., Soldo, A., Stump, E., & Williams, J.T. (2015). European Red List of marine fishes. Luxembourg: Publications Office of the European Union.

Patroni, J., Simpson, G., & Newsome, D. (2018). Feeding wild fish for tourism—A systematic quantitative literature review of impacts and management. International Journal of Tourism Research, 20(3), 286-298.

Pauly, D., Christensen, V., Guenette, S., Pitcher, T., Sumaila, R., Walters, C., Watson, R., & Zeller, D. (2002). Towards sustainability in world fisheries. Nature. 418. 689-95. 10.1038/nature01017.

Pires, N. M., Garla, R. C., & Carvalho, A. R. (2016). The economic role of sharks in a major ecotourism archipelago in the western South Atlantic. Marine Policy, 72, 31-39.

Rodger, K., Smith, A., Newsome, D., & Moore, S. A. (2011). Developing and testing an assessment framework to guide the sustainability of the marine wildlife tourism industry. Journal of Ecotourism, 10(2), 149-164.

Rodger, K., Smith, A., Davis, C., Newsome, D., & Patterson, P. (2010). A framework to guide the sustainability of wildlife tourism operations: examples of marine wildlife tourism in Western Australia.

Simpfendorfer, C. A., & Dulvy, N. K. (2017). Bright spots of sustainable shark fishing. Current Biology, 27(3), R97-R98.

Sutcliffe, S. R., & Barnes, M. L. (2018). The role of shark ecotourism in conservation behaviour: Evidence from Hawaii. Marine Policy, 97, 27-33.

Tapper, R. (2006). Wildlife watching and tourism: a study on the benefits and risks of a fast growing tourism activity and its impacts on species. UNEP/Earthprint.

Topelko, K. N., & Dearden, P. (2005). The shark watching industry and its potential contribution to shark conservation. Journal of Ecotourism, 4(2), 108-128.

Torres, P., Bolhão, N., da Cunha, R. T., Vieira, J. A. C., & dos Santos Rodrigues, A. (2017). Dead or alive: The growing importance of shark diving in the Mid-Atlantic region. Journal for Nature Conservation, 36, 20-28.

Vianna, G. M. S., Meeuwig, J. J., Pannell, D., Sykes, H., & Meekan, M. G. (2011). The socioeconomic value of the shark-diving industry in Fiji. Perth: University of Western Australia. 26p.

Vianna, G. M., Meekan, M. G., Pannell, D. J., Marsh, S. P., & Meeuwig, J. J. (2012). Socio-economic value and community benefits from shark-diving tourism in Palau: a sustainable use of reef shark populations. Biological Conservation, 145(1), 267-277.

Vianna, G. M., Meekan, M. G., Rogers, A. A., Kragt, M. E., Alin, J. M., & Zimmerhackel, J. S. (2018). Shark-diving tourism as a financing mechanism for shark conservation strategies in Malaysia. Marine Policy, 94, 220-226.

Worm, B., Davis, B., Kettemer, L., Ward-Paige, C. A., Chapman, D., Heithaus, M. R., ... & Gruber, S. H. (2013). Global catches, exploitation rates, and rebuilding options for sharks. Marine Policy, 40, 194-204.

Zimmerhackel, J. S., Kragt, M. E., Rogers, A. A., Ali, K., & Meekan, M. G. (2019). Evidence of increased economic benefits from shark-diving tourism in the Maldives. Marine Policy, 100, 21-26.

CHAPTER 1

CHALLENGES AND CONSERVATION POTENTIAL OF SHARK-DIVING TOURISM IN THE MACARONESIAN ARCHIPELAGOS

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CHAPTER 1

Challenges and conservation potential of shark-diving tourism in the Macaronesian archipelagos

Abstract

Macaronesia is formed by some of most isolated oceanic islands of the Atlantic Ocean. This region is typically heavily exploited by fisheries; however, in recent years, marine wildlife tourism has become popular and a shark-diving industry has emerged, potentially presenting an alternative for the sustainable use of sharks. Combining a literature review with interviews with dive operators conducting shark encounters in the Macaronesian archipelagos, we provide an overview of the challenges and conservation potential of shark-diving tourism for these territories. Owing to the regular presence of important shark species for tourism and the growth of the scuba-diving industry, shark-diving has potential to expand over the region. Yet, the overlap between European industrial fishing pressure and shark populations, coupled with the unregulated recreational and artisanal fishing sector in the Canary Islands and Cape Verde, may jeopardize the sustainability of the shark-diving industry. However, the economic benefits for local communities directly and indirectly produced by shark-diving tourism suggest local benefits, fostering stronger shark conservation in Macaronesia.

Keywords: Shark-based tourism, Shark fisheries, Shark conservation, Azores Islands, Canary Islands, Cape Verde.

1. Introduction

Historically, sharks were generally considered an incidental catch in fisheries targeting other more valuables species (Dulvy et al., 2017); however, in recent decades the global demand for shark products has progressively increased, shifting the capture of sharks from bycatch to target taxa in many fisheries (Dent & Clarke, 2015). Sharks are caught by fishing fleets from all over the world, with an estimated catch of up to 100 million individuals per year (Worm et al., 2013). In 2015 the global market for shark products was estimated to generate roughly USD $1 billion traded annually (Dent & Clarke, 2015). Yet, poor regulation of shark fisheries, including the common practice of shark-finning in the High Seas (Chen & Phipps, 2002; Lehr, 2015; Dulvy et al., 2017), has triggered a precipitous worldwide decline of many shark populations (Worm et al., 2013; Dulvy et al., 2014). Due to overfishing, sharks are currently accepted worldwide as a group for priority conservation (Dulvy et al., 2014), with 20% of the nearly 500 known shark species in the Red List of the International Union for Conservation of Nature – IUCN threatened with extinction (IUCN, 2013).

Whereas there are numerous fisheries management tools utilized to prevent shark overexploitation, effective implementation of these approaches is restricted to few species and in developing countries with strong fisheries management systems in place (Simpendorfer & Dulvy, 2017; Ferretti et al., 2020). Unfortunately, effective fisheries management is the exception, not the rule for most regions around the world (Pauly et al., 2002), and in light of these challenges, new economic perspectives, which may allow a more sustainable use of sharks are now being considered, such as shark-diving touristic industry. This type of non-consumptive use of sharks, first developed in the late 20th century (Topelko & Dearden, 2005), has been growing in popularity and today is a global phenomenon (Gallagher and Hammerschlag, 2011). In recent years, sharks have become important attractions in many dive sites around the world, contributing to local, regional and national economies in North America, Central and South America, Europe, Greater Caribbean, Oceania, North Africa and Middle East, Asia and Indonesia and Southern and Eastern Africa (Topelko & Dearden, 2005; Gallagher and Hammerschlag, 2011; Vianna et al., 2011; Haas et al., 2017; Huveneers et al., 2017; Mieras et al., 2017; Zimmerhackel et al., 2019). Observing these animals in their natural habitat either from boats or underwater with snorkel or scuba gear is a niche sector in the rapidly developing marine tourism market (Cater, 2008). Aside from producing positive changes in tourist knowledge, attitudes, and conservation behaviours (Gallagher et al., 2015; Sutcliffe et al., 2018) and making significant contributions to national economies, the revenues from this industry may support the livelihood of local communities, and support conservation strategies and management (Vianna et al., 2012, 2018).

Shark-diving tourism has also seen an increase in academic attention. A review by Gallagher et al. (2015) found that, until 2014, 47 original research articles focusing on some aspect of the shark-diving tourism industry were published, with 47% of these studies consisting of socio-economic analyses conducted at many scales. These studies generally concluded that, where shark-diving tourism is viable, the economic benefits from shark conservation are potentially larger than what can be achieved by fisheries exploiting the same resources (Clua et al., 2011, Vianna et al., 2011; Vianna et al., 2012; Cisneros-Montemayor et al., 2013). For example, Cisneros-Montemayor et al. (2013) estimated the global value of shark-diving industry to be around USD $ 314 million in 2011, directly supporting around 10,000 jobs. While the accuracy of these estimates has been a source of debate (see Brunnschweiler and Ward-Paige, 2014), many studies have demonstrated that shark-based tourism has driven shifts

in the socio-economic importance of sharks from a fisheries product to a more valuable non-consumptive resource in many tourist destinations around the world (Gallagher et al., 2015). Therefore, identifying and assessing new potential sites for shark-diving tourism development is strongly encouraged in the greater literature (Topelko & Dearden, 2005; Cisneros-Montemayor et al., 2013), particularly in those regions experiencing significant shark populations declines due to overfishing, such as in the Northeast Atlantic (Gibson et al., 2008). However, despite these declines, only around 10% of the scientific studies published on shark-diving tourism have focused on the Atlantic Ocean (Gallagher et al.,2015), despite the high number of shark-diving operations in this region (Gallagher & Hammerschlag, 2011) and to date no study has focused on the NE Atlantic in particular.

In the present study, we address this gap by mapping and contextualizing the opportunities, both current and potential, for shark-diving tourism within the Macaronesian archipelagos (the Azores, Madeira, Canary Islands and Cape Verde). This biogeographic region contains some of the highest rates of marine biodiversity in the North-East Atlantic Ocean (Nieto et al., 2015), whereby species from diverse geographic areas meet (Evans, 2010). It is particularly characterized by the presence of highly migratory pelagic shark species with moderate to high risk of extinction such as blue shark (*Prionace glauca*) (Rigby et al., 2019a) and shortfin mako shark (*Isurus oxyrinchus*) (Rigby et al., 2019b), together with other highly threatened demersal species such as angel shark (*Squatina spp*.) (Morey et al., 2019). This region is also a hotspot for commercial fishing activities from small to large scale fleets, which pose significant risks to these species (Carneiro, 2012; Barker et al. 2016; Queiroz et al. 2019). Here we summarize the challenges of the shark-diving industry in the Macaronesian archipelagos based on the analysis of the shark-related activities in the regional context, namely fisheries and tourism, and present the perspectives and opportunities for potential expansion of this market.

2. Methods

2.1. Study area

Macaronesia is a biogeographic region whose area extends from the North-East Atlantic to the Central-East Atlantic Ocean, encompassing five archipelagos, in decreasing order of latitude: the Azores, Madeira, Salvages, Canary Islands and Cape Verde (Fig.1). With a total land area of approximately 15,000 km^2 Macaronesia includes 40 islands > 1 km^2 stretching from 14.8°N (Brava, Cape Verde) to 39.7°N (Corvo, Azores) and from 13.4°W (Roque del Este, Canary Islands) to 30.9°W (Flores, Azores) (Torre et al., 2019). Summing the land surface, the Exclusive Economic Zone (EEZ) and the Extended Continental Shelf (ECS), the total area of the Portuguese Autonomous Regions of Azores and Madeira (including Salvages islands), the Spanish Autonomous Community of Canary Islands and the Republic of Cape Verde, is 2,467,622 km^2, divided into 131 municipalities (Menini et al., 2018). As part of the territory of European Members states despite being remotely detached from the European continent, the Azores, Madeira and Canary Islands are considered European Outermost Regions (Ors) (Azevedo, 2017).

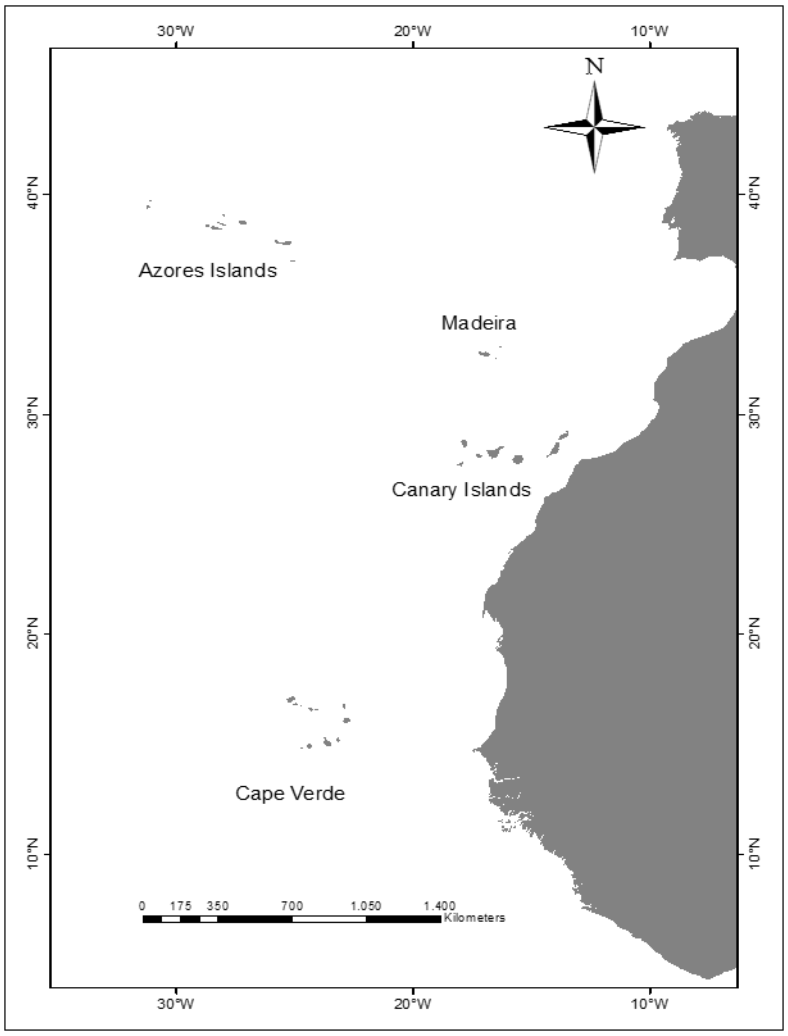

Fig. 1. Geographic position of the archipelagos and islands of Macaronesia.

2.2. Tourism and shark-diving tourism in the Macaronesian archipelagos

The structure of the economy in Macaronesia is oriented towards services where tourism has a significant role, especially in Madeira and the Canary Islands (Menini et al., 2018). Tourism is the main economic activity in the Canary Islands with roughly 15 million visitors a year, accounting for approximately 31% of total Gross Value Added (GVA) and 35% of total employment (Gobierno de Canarias, 2015). For Madeira, tourism is also the most important sector of the regional economy accounting to almost 21 % of GVA and 20 % of employment (EU Commission, 2017). The tourism industry in the Azores is far less well developed than those of Madeira or the Canary Islands, but this activity has been progressively gaining popularity (Azevedo, 2017). Akin to the Azores, Cape Verde tourism activity is nascent; however, it is gaining in significance, especially coastal tourism (EU Commission, 2017). This industry accounts for 50% of the services sector, which represented about 70% of Gross Domestic Product (GDP) in 2016 (Nshimyumuremyi, 2018). Overall, coastal tourism shows great potential all around the Macaronesian Region specifically those activities that take advantage of the marine environment and its resources and the coastal culture such as whale and bird watching, recreational fishing tourism and marine gastronomy, among others (EU Commission, 2017).

2.3. Shark fisheries in the Macaronesian archipelagos

Fishing is an ancestral practice in Macaronesia, traditionally artisanal and subsistence with the use of vessels with less than 12m in length (Menini et al., 2018). This sector has shown a decreasing trend in number of vessels and fishers in the Ors due to the reduction of fleets and fleet capacities established by the European Union (EU), in order to maintain a sustainable balance between fishing capacity and fishing opportunities (Goulding & Stobberup, 2015). Yet, fisheries in the region still suffer from lack of effective monitoring and surveillance, making it difficult to deter illegal fishing (EU Commission, 2017). Against this backdrop, sharks are common bycatch in many fisheries, from multinational industrial companies to artisanal fishers, including demersal trawls, longlines, or gillnets, and some species are specifically targeted and heavily fished by international large-scale fleets (Torres et al., 2016). Domestic shark fisheries also exist in Macaronesia and have traditionally exploited small bottom-living coastal sharks and, more recently, deep-water sharks (Hareide et al., 2007; Diop & Dossa, 2011; Barker et al., 2016; Lopes et al., 2016; Torres et al., 2016). Industrial longlines land most of the shark catch; however, the impact of the local sector on regional stocks of sharks is usually underestimated (Das & Afonso, 2017). According to Food and Agriculture Organization (FAO), the major shark fishing entities on these waters are Spain, France, the UK and Portugal (Gibson et al., 2008). Spain is the third-highest shark catching country in the world and one of the largest producers and exporters of shark fins – mostly to East and Southeast Asian markets (Dent & Clarke, 2015). Moreover, Spain is the main trader of shark meat in Europe and is responsible for importing and exporting most of shark fins and shark meat in the region (Lehr, 2015).

According to EUROSTAT data on shark catches by EU fleets in the Atlantic, 69% and 72% of Spanish and Portuguese surface longline Atlantic catches, respectively, are comprised of sharks, mainly blue shark (*Prionace glauca*) and shortfin mako shark (*Isurus oxyrinchus*) (Oceana, 2009); however, shark catches from both countries are poorly documented and generally underreported (Hareide et al., 2007). A recent global analysis of shark habitat use and fishing activity found that industrial fisheries in the North Atlantic overlap with nearly 80% of the space use of blue sharks, which exhibit moderate densities in the Macaronesian Region (Queiroz et al., 2019). Other species such as threshers (*Alopias spp.*), silky (*Carcharhinus falciformis*), hammerhead (*Sphyrna spp.*), and oceanic whitetip (*Carcharhinus longimanus*) sharks are also regularly caught (Fowler & Séret, 2010). The majority of Atlantic shark catches from Spanish, Portuguese and UK longliners are landed in the harbours of St. Vincente and Mindelo in Cape Verde, and Vigo and Las Palmas in Spain (Oceana, 2009). The Spanish ports of Vigo and Las Palmas in the Canary Islands are the European centers for the shark fin trade (Lehr, 2015) and major entry points to the EU market for illegal shark products (Pramod et al., 2006).

Shark fisheries occurring in Macaronesia are mainly controlled by the European Union fisheries management, under the EU Common Fishery Policy (CFP) and the fisheries partnership agreement with Cape Verde. Spain, France and Portugal pay to West-African countries for access rights to exploit fish stocks from their EEZ, and a budgetary support for implementing the Sustainable Fishery Policy (SFP) (Goulding & Lda., 2016). The most relevant Regional Fisheries Management Organization (RFMO) for the Macaronesian Region shark catches is the International Commission for the Conservation of Atlantic Tunas (ICCAT). This organization, concerned with the oceanic, pelagic, and highly migratory elasmobranchs, requires contracting parties to annually report catch data for each shark species caught in association with the fisheries ICCAT manages (Lehr, 2015). However, the lack of species-specific statistics from EU shark fisheries, landings, markets and trade (Hareide et al., 2007), underreporting to the ICCAT Secretariat (Lehr, 2015) and little monitoring of what is

actually caught, particularly in Cape Verdean waters (Carneiro, 2012), remain some acknowledged problems. In Table 1, we summarized the principal shark-fishing regulations concerning the Macaronesian archipelagos.

Table 1: Historical overview of shark fishing regulations on the Macaronesian waters

Shark fishing regulations on the Macaronesian waters	
2003	Council Regulation (EC) 1185/2003 on the removal of fins of sharks on board vessels established a general prohibition of the practice of shark finning.
2005	The EU banned the use of trawls and gillnets in waters deeper than 200 m in the Azores, Madeira and Canary Island areas in order to protect deep-water sharks. Portuguese dogfish (*Centroscymnus coelolepis*), leafscale gulper shark (*Centrophorus squamosus*), and kitefin shark (*Dalatias licha*) are managed under TACs (total allowable catches) in the Azorean waters.
2013	The EU established a strict no finning regulation for all vessels in European Union waters and all European Union-registered vessels, mandating that all sharks be landed with fins still attached to their bodies.
2014	The new European Common Fisheries Policy introduced a discard ban and landing obligation for pelagic species.
2015	According to the Council Regulation (EU) 2015/104, most of the sharks listed by the Convention on International Trade in Endangered Species of Wild Fauna and Flora – CITES Appendix I, such as white shark (*Carcharodon carcharias*), basking shark (*Cetorhinus maximus*), and species listed under Appendix II, such as the porbeagle (*Lamna nasus*) and all hammerheads (*Sphyrna spp*) may not be fished, retained on board, transhipped or landed by any EU vessels.
2016	Under the Council Regulation (EU) 2016/72, the EU also included in these terms the angel shark (*Squatina squatina*) in European waters, and oceanic whitetip shark (*Carcharhinus longimanus*), silky shark (*Carcharhinus falciformis*), bigeye thresher sharks (*Alopias superciliosus*) and hammerhead sharks of the Sphyrnidae family (except for the *Sphyrna tiburo*) in the ICCAT convention area.
2019	Three species of angel shark (*Squatina squatina*, *Squatina aculeata* and *Squatina 34xploit*) have been registered by the Spanish Ministry for Ecological Transition in the Spanish Catalog of Threatened Species, under the category of Endangered Species. Any action taken with the purpose of killing, capturing, persecuting, disturbing or trading with them and any action that destroys or deteriorates their habitat or breeding areas is prohibited.

2.4. Data collection

We collected qualitative and quantitative data about shark-related activities in Macaronesia from a broad bibliographic review and documental analysis on the following subjects: shark-based tourism, shark fisheries and shark conservation. For this purpose, we used peer-reviewed publications, published PhD theses, government, NGO and newspaper reports, internet websites, UN databases and personal enquiries. Peer-reviewed publications were selected from the Science Citation Index Database (Web of Science) and Google Scholar using the keyword searches “sharks in Macaronesia”, “sharks in Azores”, “sharks in Madeira”, “sharks in Canarias” and “sharks in Cabo Verde”.

From September to December 2019, we conducted interviews with diving operators in each archipelago of Macaronesia in order to understand the scale and potential about the shark-diving activity they provide. Prior to this, we identified and quantified all the official diving centers in the region through online search on the websites of national and regional authorities from Macaronesia and also performed an online search to identify non-official diving centers. We used the keyword searches “diving centers in Azores”, “diving centers in Canarias”,

"diving centers in Madeira" and "diving centers in Cabo Verde". We included in our analysis those companies with an official website advertising different scuba-diving activities.

Then, we identified diving centers specifically advertising shark encounters as an associated service. The criteria used to select these companies included: (a) a banner on the website homepage featuring a shark image and/or text advertising a shark encounter and (b) operations directly promoting and pricing a specific shark encounter. Moreover, we also include in our analysis those companies mentioning sharks on their websites as part of the attractions of a given diving or snorkeling activity.

After we identified and quantified all the diving centers providing shark encounters in the Macaronesian archipelagos, we attempted to contact all of them and were successful in obtaining reply from 30-40% in each archipelago. The criteria used to identify those companies to be interviewed included: (a) conduct specific shark-diving operations; (b) be official diving centers and (c) include diversity in terms of geographic distribution, seniority and size of the operations. Thought the interviews, we quantified the scope of their operation through the following parameters: (a) number of years providing scuba-diving activities; (b) number of operations per year; (c) % of shark encounters operations; (d) price of shark-diving or shark encounters operations; I shark species observed; (f) frequency of shark observation and (g) seasonality. We also included an open-ended question about the potential of shark-diving tourism in each archipelago.

Since there are limited data available from the official sources, we used the *Sea Around Us* – research initiative database (http://wwwseaaroundus.org) to elicit the volume of shark catches in the Exclusive Economic Zones (EEZ) of the Macaronesian archipelagos. We also collected the total landed values of sharks in order to compare the revenues generated from shark fisheries and shark-diving tourism. This information was gathered with the aim of understanding the scale of shark fisheries in the region and how this could affect to potential expansion of shark-diving industry.

3. Results

3.1. Bibliographic review and documental analysis

Our review revealed 53 published shark-related studies in terms of fisheries, tourism and conservation in the Macaronesian archipelagos from 2003 to 2019 (Supplementary material 1). This list includes original research articles (26 studies); technical reports (14 studies); published theses (5 studies); books (3 studies); chapters (3 studies) and conference papers (2 studies). Most of the studies focused on the Azores Islands (49%), followed by Macaronesia and the Canary Islands with 12 and 10 studies, respectively. Fisheries comprised the majority of studies (58%), whereas 25% were focused in shark-diving tourism. Of all the studies focused in tourism, approximately 77 % occurs in the Azores Islands. Despite the shark-diving industry in the Azores is still in its infancy (Torres et al., 2017), it is not surprising that this archipelago dominates the literature, as this is the most popular shark-diving destination in Macaronesia. From this review, we synthesized the primary information related to shark-diving tourism industries for each of the archipelagos within the Macaronesia below.

3.2. Overview of tourism and shark-diving in the Macaronesian archipelagos, as synthesized from our literature review.

Azores

The Azores is an emerging touristic destination for marine-related activities such as sailing, surfing, whale and dolphin watching and, more recently, scuba-diving and shark-diving (Calado et al., 2011). Shark-diving operations in the Azores began in 2011 (Bentz et al., 2014) and in 2014 the estimated revenues generated by this industry were around 2 million Euros (~2,250,000 USD). Shortfin mako sharks (*Isurinus oxyrinchus*) and blue sharks (*Prionace glauca*) are the principal attractions of this diving experience, which is operated only in Faial and Pico Islands (Torres et al., 2017). The dives are conducted offshore, in waters with depths of about 200 m and use chum buckets to lure the sharks (Torres, 2017). Usually, divers do not directly interact with the sharks but hold on to weighted lines to avoid being carried away by the currents (Bentz et al., 2014).

Swimming with whale sharks (*Rhincodon typus*), either with snorkel or scuba gear, is another shark-based tourism activity offered in the Azores, mainly near the island of Santa Maria (Bentz et al., 2014). Since 2008 there has been an increase in frequency of whale sharks probably due to change in migratory patterns as a result of a possible change in water conditions (Calado et al., 2011; Afonso et al., 2014). Bentz et al. (2014) observed that local fishers of Santa Maria cooperate with the dive centers informing when a whale shark was sighted in exchange of the economic benefits from the presence of snorkelers.

Canary Islands

The Canary Islands are a very popular tourist destination for scuba divers. In 2009 there were 84 official diving centers distributed across the archipelago (De la Cruz Modino et al., 2010). The most popular islands for diving are El Hierro, Fuerteventura, Gran Canaria, Lanzarote and Tenerife (Meyers et al., 2017). According to De la Cruz Modino et al. (2010), sharks and rays are a main attraction of diving tourism in the archipelago, and in 2009 were responsible for generating one-third of their total economic revenues of the industry. These authors estimated elasmobranch diving in the Canarian Archipelago to generate € 17.7 million (around USD $24.6 million) in 2009, supporting 429 jobs (De la Cruz Modino et al., 2010). Demersal elasmobranch species are often sighted and the angel shark, in particular, is one of the most commonly encountered species by recreational scuba divers (Barker et al., 2016). It is also possible to sight whale sharks (*Rhincodon typus*), hammerhead sharks (*Sphyrna zygaena*) and smalltooth sand tiger (*Odotapis ferox*), but these sightings are sporadic (De la Cruz Modino et al., 2010).

Cape Verde

Diving is one of the main tourist attractions in Cape Verde due to the relatively lightly impacted tropical marine environment by anthropogenic factors (Oliveira, 2016). Sal Island is the most popular destination for diving, while there are no socioeconomic data on Cape Verde's diving industry, there are at least six dive centers operating in the Santa Maria Bay, which is a major tourism destination (Dive-report, 2016). The most recent validated check-list of coastal fish from the Cape Verde Islands (Wirtz et al. 2013) lists a total of 315 fish species, of which 22% are elasmobranchs (sharks, rays and skates). The most frequently shark species observed in Cape Verde's coast are: nurse shark (*Ginglymostoma cirratum*), dusky shark (*Carcharhinus obscurus*), lemon shark (*Negaprion brevirostris*), smooth hammerhead (*Sphyrna zygaena*), tiger shark (*Galeocerdo cuvier*), Galapagos shark (*Carcharhinus galapagensis*), whale shark (*Rhincodon typus*) and sand tiger shark (*Carcharias taurus*),

among others (Wirtz et al. 2013). One of the most popular tourist attractions in Cape Verde is the observation of lemon sharks in Shark Bay (Santa Maria, Sal Island) either from shore or as an in-water activity.

Madeira

Madeira is experiencing a steady increase in marine-based activities such as whale watching, scuba-diving, surfing, body boarding, windsurfing, stand up paddling, recreational fishing, underwater archaeology, among others (EU Commission, 2017). However, we found no evidence of shark-diving activities being advertised or carried out despite the presence of various species of elasmobranchs in this archipelago (Correia et al., 2016).

3.3. Shark-diving industry profiles in the Macaronesian archipelagos

We identified 228 diving centers in the Macaronesian archipelagos of which ~64% are located in the Canary Islands (145 companies), followed by the Azores Islands and Madeira with 58 and 13 companies, respectively (Table 4). We found that 129 companies advertised shark encounters, of which 120 consisted on general shark encounters and 9 on specific shark encounters. General shark encounters were defined as those encounters where sharks are not the main attraction of diving activities. The majority of companies advertising general shark encounters were located in the Canary Islands (108 companies), followed by Cape Verde and the Azores with 8 and 4 companies respectively. Regarding those companies that advertised specific shark encounters, 8 were located in the Azores and 1 in the Canary Islands. Madeira was the sole archipelago where shark encounters were not advertised.

Table 2: Summary table of diving centers in the Macaronesian archipelagos from internet search.

Macaronesian archipelago	Number of diving centers	Number of diving centers advertising specific shark encounters	Number of diving centers advertising general shark encounters
Azores Islands	58	8	4
Madeira	13	0	0
Canary Islands	145	1	108
Cape Verde	12	0	8
Total	228	9	120

We obtained information to assess the shark-diving industry potential in the region based on the interviews conducted with 26 dive operators advertising shark encounters in the Macaronesian archipelagos: 2 dive centers from the Azores (~20%); 21 dive centers from the Canary Islands (~20%) and 3 dive centers from Cape Verde (~35 %). We also contacted 2 dive operators from Madeira; however, they could not offer any information about shark encounters since these were unreported. Most of respondents selected (1 per company) were dive guides between 30-40 years old, with more than 5 years working in each dive center. In some cases, we interviewed the owners of these companies, which allow us to gather a wider information about the subject of research. We summarized our results in Table 2 and 3.

Overall, we found that the Azores is the only archipelago where it is possible to undertake specific shark-diving activities, mainly in Faial and Pico Island. Some dive centers in Santa

Maria Island also provide opportunistic shark encounters such as snorkeling with whale sharks. Blue sharks are the main attraction of shark-diving operations in the Azores, which occurs only during summer season (from July to September). According to local dive operators, shark-diving activities represent less than 5 % of total dive operations per year. The operators identified the regular occurrence of blue sharks and the international recognition of the dive spot as the principal strengths of the operation. However, the operators also expressed major concerns regarding overfishing and its potential threat to the shark-diving industry and highlighted the need of implementation of marine protected areas and/or shark sanctuaries.

Table 3: Shark-diving industry profiles in the Macaronesian archipelagos.

	Number of years providing scuba-diving activities	Number of dive trips per year per company	% of shark-dive operations* or general shark encounters** per year per company	Cost (€) of a shark dive trips* or general shark encounters**	Shark species observed	Frequency of shark observation	Seasonality
Azores Islands	17 ± 7	1250 ± 1060	3.38 ± 1.9 *	172.5 ± 3.5 *	Blue shark and mako shark	From to 1 to 6 blue shark per immersion, normally 2-3. Mako shark is quite rare to observe in the last years	From June to October
Canary Islands	15.2 ± 11.1	2045 ± 1403	8.47 ± 14.8 **	45.13 ± 6.7 **	Angel shark in most of the islands. Smalltooth sand tiger in El Hierro. Others: hammerhead shark, tope shark and blue shark	Gran Canaria: 1-3 angel sharks per immersion. Fuerteventura: 39xplo 20 angel sharks per immersion, normally 3-4. Lanzarote: 1-3 angel sharks per immersion. Tenerife: 2-4 angel sharks per immersion. El Hierro: 2-3 smalltooth sand tigers per immersion	Angel shark: November-June in Gran Canaria, November to March in Fuerteventura and Tenerife, October-May in Lanzarote. Smalltooth sand tiger: June-November in El Hierro
Cape Verde	12.75 ± 11.9	1400 ± 583	10.75 ± 10.3 **	65 ± 16.8 **	Lemon shark, nurse shark, black tip shark, whale shark, hammerhead shark, sand tiger shark, Galapagos shark, thresher shark, tiger shark and milk shark	Lemon shark, nurse shark and blacktip shark are the most abundant species. From 1 to 8 nurse sharks. In average 2-3 nurse sharks per immersion	Generally, between April-December. Nurse shark: whole year. Thresher shark: April. Whale shark: September-November

Note: Madeira was not included in the table since shark encounters were not reported as stated in our results.

The Canary Islands is the archipelago with the most developed scuba-diving industry in Macaronesia accounting the largest number of diving centers in the region (145 companies) and the highest number of diving operations per company (2,045 trips on average per year). Although one company in the Canary Islands advertised "diving with angel sharks" on its website, we verified that these encounters are only opportunistic. Angel sharks are the most observed species in these islands, mainly in Gran Canaria, Lanzarote, Fuerteventura and Tenerife, during winter and spring season. Although the majority of Canarian dive operators supported the development of a shark-diving industry in this archipelago, a few of them disapproved it. The principal strengths mentioned were: well-established scuba-diving industry in the European market and high probability of angel shark sightseeing. However, most of the operators indicated legal barriers established by local authorities as the main obstacle for developing a shark-diving industry. All the operators advocate for implementation of marine protected areas and/or shark sanctuaries and to raise public awareness of ecological and economic benefits of shark-diving tourism.

Cape Verde is the less developed archipelago in terms of scuba-diving industry with only 12 diving centers. However, this sector is growing fast as the number of companies has doubled in recent years. Despite shark-diving industry is non-existent, local dive operators pointed out that sharks in Cape Verde are sighted in roughly 10% of scuba-diving operations. Moreover, they reported that more than 50 % of dive tourists come to Cape Verde expecting to encounter sharks. Operators highlighted principal strengths as the diversity and regular presence of shark species in their waters and optimal conditions for diving during most of the year. However, they noted that overfishing is the main threat for the development of a shark-diving industry. They also expressed the need for better surveillance and monitoring of existent marine protected areas and increasing public awareness of the ecological and economic benefits of shark-diving tourism.

Table 4: Conclusions from the open-ended question about the potential of shark-diving industry in the Macaronesian archipelagos.

Azores Islands	Canary Islands	Cape Verde
Current situation		
Shark-diving industry is an emerging activity in the Azores Islands. General diving tourism is growing up fast in the region.	There is no shark-diving industry in Canary Islands. Dive tourism is a well-established industry in the archipelago.	There is no shark-diving industry in Cape Verde. Some marine tourism companies provide shark-watching activities from the shore since the abundance of lemon sharks.
Strengths and Opportunities		
This activity has potential to expand as new dive spots for shark-diving operations can be explored.	Angel shark is the specie with highest potential for develop shark-dive operations owing to high rate of encounters with dive tourists in most of islands during winter season. This activity would need to be well prepared and duly regulated. Diving with smalltooth sand tiger sharks in El Hierro is not every year activity but its popularity has increased in the last years. These operations are regulated in order to avoid negative impacts. Dive operations with blue shark and mako shark could be developed in the Canary Islands as occur in the Azores.	There is a great potential for this activity as the diverse and regular presence of shark species on their waters, non-aggressive species and well visibility for diving. A shark-diving industry using chumming could be developed similarly to Azores if it is well prepared.
Weakness and Threats		
Shark-diving operations only occur during 3 months per year. Impact by fisheries and insufficient number of marine protected areas are the main concerns.	Angel shark sightseeing is not guaranteed; existent legal barriers; endangered status of the specie and possible touristic impact on shark behavior.	The number of shark populations has diminished due to overfishing from international fleets. There are local conflicts with dive centers probably since only foreigners own all diving centers.
Measures required		
The creation of a shark sanctuary and international marketing will be a big contribute to Azorean diving.	Implementation of marine protected areas and/or shark sanctuaries and awareness of ecological and economic benefits of shark-diving tourism to local authorities.	Better surveillance and control of marine protected areas are needed. Shark sanctuary could be a solution.

Note: Madeira was not included in the table since shark encounters were not reported as stated in our results.

3.4. Volume of shark catches and landed value in the Macaronesian archipelagos

The total volume of commercial elasmobranchs catches between 2004 and 2014 in the Macaronesian archipelagos EEZ was 28,620 t with a total landed value estimated to be over USD $ 808.6 million. The Azores EEZ had the highest quantity with a total 22,360 t and landed value in order of USD $ 763 million. These were followed by Madeira with 3,030 t (USD $ 27.9 million), Cape Verde with 1 980 t (USD $ 16.6 million), and finally the Canary Islands with 1,250 t (USD $ 1.1 million). There is a clear decreasing trend of shark catches in all the archipelagos since 2011, with some indication of stabilization in the volume caught since 2013. This may be partially explained by the reduction of number of vessels in the Macaronesian waters and other regulations established by the European Common Fisheries

Policy (CFP) for controlling the shark fishing such as the reduction of quotas and the prohibition of retention of certain sharks and rays species. Reported data on catches of large species of sharks in the Canary Islands is limited (Castro et al. 2015), however, the reconstructed catches of sharks greater than 90 cm displayed a decreasing trend, similar to that found in commercial shark and ray species (Fig. 3).

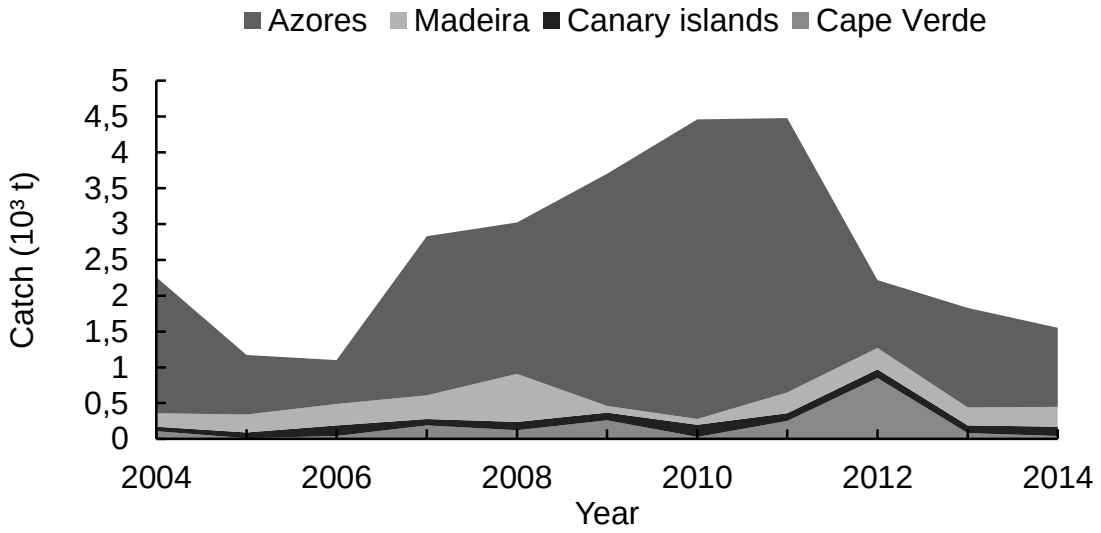

Fig. 2. Sharks and rays (commercial groups) catches in the Exclusive Economic Zones of the Azores, Madeira, Canary Islands and Cape Verde between 2004 and 2014. Source: Adapted from the *Sea Around Us* Database (2021).

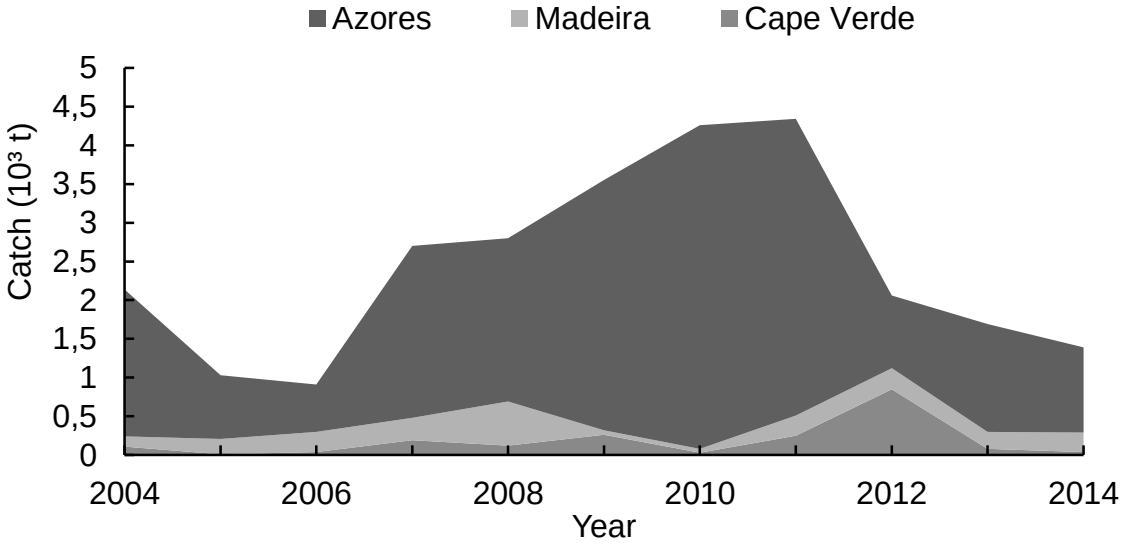

Fig. 3. Sharks (>90cm) catches in the Exclusive Economic Zones of the Azores, Madeira and Cape Verde between 2004 and 2014. Catch data from the Canary Islands is lacking since this information was not available. Source: Adapted from the *Sea Around Us* Database (2021).

4. Discussions

4.1. Potential for expansion of the shark-diving industry in the Macaronesian archipelagos

Scuba-diving tourism is a well-established activity in all the Macaronesian archipelagos; however, shark-diving tourism is still largely undeveloped. The Azores stands out as the sole archipelago in Macaronesia offering specialized shark-diving operations. While shark-diving activities represent less than 5% of the total annual dive operations in the Azores, in 2014 this sector was estimated to generate more than USD $2 million (Torres et al., 2017) and according to the dive operators it has experienced an increasing trend since then. In Cape Verde and the Canary Islands, sharks are one of the main attractions of some scuba-diving operations; however, dive operators in both archipelagos stated that these encounters are mainly opportunistic. In 2009, De la Cruz et al. (2010) intended to estimate revenues generated by elasmobranch diving in the Canary Islands; however, this study was mostly focused on sighting of rays and may have not reflect the economic value of sharks as an attraction in Canarian diving industry, thus a detailed evaluation of economic benefits associated with shark-diving in this archipelago is necessary.

Despite the small number of specialized shark-diving operations in Macaronesia, the shark-diving industry has the potential to expand in the Azores and to become a specialized market in the archipelagos where it is still inexistent. Shark divers worldwide are drawn to dive spots where sharks can be encountered on a consistent basis and observed at close range, preferably in clear waters (Topelko & Dearden, 2005). As observed in our results, these elements are present in the Macaronesian Region. Many popular species for shark-diving can be found regularly or frequently in most of the archipelagos, these include blue sharks, shortfin makos and whale sharks in all the Macaronesian waters, lemon and nurse shark in Cape Verde or angel shark in the Canary Islands (Table 5, Calado et al., 2011, Wirtz et al., 2013; Barker et al., 2016; Torres et al., 2017; Queiroz et al., 2019). The established shark-diving industry operating in the Azores suggest that regular and reliable encounters can support operations at least for pelagic species (i.e. blue and mako sharks) in offshore environments. Regular coastal shark-diving operations are likely to be logistically less challenging; however, these can potentially face challenges due to lower abundance of sharks due to fishing pressure.

Each of the archipelago in Macaronesia has particular features to develop shark-diving activities. In the Azores, dive operators stressed that aside from the current shark-diving spots there are other potential areas where shark-diving operations could take place given the abundance of blue sharks on their waters. Also, while swimming with whale sharks is opportunistic in all Macaronesian archipelagos, the Azores is the European dive destination with highest probability to encounter them during their seasonal migrations (Calado et al., 2011). The Canary Islands is the only place in the Northeast atlantic where angel sharks may be sighted regularly (Barker et al., 2016). Since 2019, these sharks are under stricter legal protection in the archipelago. According to local dive operators, angel sharks can be observed mostly during winter season, and recreational scuba divers have opportunistic encounters with them in approximately 10% of the overall dives conducted annually, indicating that shark-diving could be advertised as a seasonal activity. Cape Verde, as home of high diversity of warm-water marine species (Oliveira, 2016), and characterized by the regular presence of coastal sharks (Wirtz et al. 2013), offers a high probability of shark observations, even from the shore. According to Cape Verdean operators, sharks are opportunistically observed in roughly 10% of the total number of general dive operations per year; however, they highlighted that this proportion was considerably higher in previous years. Additionally, some dive

operators in the Canary Islands and Cape Verde indicated that it would be possible to develop a shark-diving industry using chumming to lure pelagic shark species, such as blue and mako shark, similarly to Azorean operations.

Other important elements considered for the selection of shark-diving spots worldwide are infrastructure and accessibility (Topelko & Dearden, 2005). In the Macaronesian archipelagos, tourism is a crucial economic sector (Gobierno de Canarias, 2015; EU Commission, 2017; Azevedo, 2017; Nshimyumuremyi, 2018; Menini et al., 2018), which led to the rapid development of new infrastructure, accommodation and facilities in coastal areas. Also, these small islands are well served with flights from Europe, Africa, and the Americas, thus, becoming attractive for both international visitors and tourism investors. Coastal recreational activities such as scuba diving are major tourist attractions with a great potential for growth (EU Commission, 2017). Although official data of the economic contribution of scuba-diving industry to the regional tourism sector are lacking, our results revealed that 228 companies provided diving activities in the archipelagos of Macaronesia in 2019, which means a large expansion on the number of dive centers in recent years, particularly in the Azores (27 companies in 2014) and Cape Verde (6 companies in 2016) (Bentz et al., 2015; Dive-report, 2016). Furthermore, the occurrence of the main shark species broadly coincides with peak tourist seasons in the Azores and the Canary Islands, while in Cape Verde these can be observed practically the whole year.

Shark-diving tourism industry in Macaronesia is thought to serve as a means of transitioning local economies from unsustainable to sustainable non-consumptive uses of marine resources as occurs in other parts of the world (Troëng & Drews, 2008; Gallagher et al. 2015). However, since the economies of these territories are highly dependent on the marine resources (Goulding & Lda, 2016), shark-diving tourism operations are very likely to interact with fisheries. Prohibitions placed on fishing sharks to protect local dive sites may create significant issues for coastal communities (Topelko & Dreaden, 2005), therefore it is necessary to implement strategies that will assure the sustainable use of sharks while safeguarding and integrating the local communities. Such approach has been successfully adopted in other popular shark-diving destinations (Vianna et al. 2012, Brunnschweiler 2010). For example, community levies paid by the shark-diving industry to adjacent fishing communities could be further explored and a mean of financial compensation not to fish at specific shark-diving spots in Macaronesia (Brunnschweiler, 2010). Other profits from the presence of shark tourists, such as the demand for local fish, could also make local fisher encouraged to support the shark-diving tourism (Vianna et al. 2012). Evidences of cooperation between local fishers and diving centers generating mutual benefits have already been found in the Azores (Bentz et al., 2014).

Table 5: Distribution, habitat, exploitation status and current human use of potential species for shark-diving in the Macaronesian archipelagos.

Shark species	Macaronesian Archipelagos	Habitat	Exploitation Status (IUCN)	Fisheries	Tourism
Blue shark (*Prionace glauca*)	All waters	Oceanic	Near Threatened	Targeted and bycatch	Shark-diving in the Azores
Short fin mako (*Isurus oxyrinchus*)	All waters	Oceanic	Endangered	Targeted and bycatch	Shark-diving in the Azores
Whale shark (*Rhincodon typus*)	All waters	Oceanic	Endangered	Bycatch	Scuba-diving in the Azores and Cape Verde
Smooth hammerhead (*Sphyrna zygaena*)	All waters	Oceanic	Vulnerable	Bycatch	Scuba-diving in Cape Verde
Angel shark (*Squatina squatina*)	Canary Islands	Coastal	Critically Endangered	Bycatch	Local scuba-diving
Smalltooth sand tiger (*Odotapis ferox*)	Canary Islands	Pelagic	Vulnerable	Data deficient	Local scuba-diving
Lemon shark (*Negaprion brevirostris*)	Cape Verde	Coastal	Near Threatened	Bycatch	Local scuba-diving
Nurse shark (*Ginglymostoma cirratum*)	Cape Verde	Coastal	Data deficient	Bycatch	Local scuba-diving
Black tip shark (*Carcharhinus limbatus*)	Cape Verde	Coastal	Near Threatened	Targeted and bycatch	Local scuba-diving
Sand tiger shark (*Carcharias Taurus*)	Cape Verde	Coastal	Vulnerable	Data deficient	Local scuba-diving
Tiger shark (*Galeocerdo cuvier*)	Cape Verde	Reef	Near Threatened	Bycatch	Local scuba-diving

4.2. The impact of shark fisheries on the expansion of the shark-diving industry in the Macaronesian archipelagos

Many of the shark species targeted by the diving industry are heavily fished by North Atlantic fisheries by national and foreign fleets (Torres et al., 2016). Thus, the potential expansion of shark-diving tourism in Macaronesia is likely to be jeopardized by pelagic industrial fisheries as both industries are competing for the same targets species. Spanish and Portuguese longline fleets are the largest shark fisheries in the Macaronesian Region (Oceana, 2009), and Spain is one of the largest producers and exporters of shark fins worldwide (Dent & Clarke, 2015). Shark catches are mostly compounded of large amounts of pelagic species such as blue shark and mako shark (Hareide et al., 2007), which are the principal tourist attractions of the Azorean shark-diving operations and potential species for shark-diving industry expansion in

Macaronesia. According to the qualitative information obtained from our interviews with the Azorean dive operators, there has been a decrease in the number of shark sightings in the last decade, which they attribute to fishing pressure. Declines in abundance of sharks can result in a substantial reduction in the demand for dive trips and economic losses not only to the dive industry, but also to the broader local tourism market (Zimmerhackel et al., 2018).

The impact of small-scale and recreational fisheries on shark populations is also a major concern since coastal sharks are the main target species for a dedicated shark-diving industry in Cape Verde and the Canary Islands. In Cape Verde, an overall reduction of biodiversity of local marine species has been reported to be caused by unregulated fishing practices (Ramos et al, 2011), and according to local operators, this has decreased the number of shark sightings in recent years. Significant bycatch of smooth hammerhead, tiger shark, and mostly lemon and nurse sharks by artisanal and semi-industrial fishers comprised (Diop & Dossa, 2011; Lopes et al., 2016), all potential target species for tourism, has been reported in this region. However, shark catch from small-scale fleets remains largely unreported (Carneiro, 2012), which suggests that the impact of this sector on shark populations is largely underestimated. In the Canary Islands shark landings are severely underreported (Castro et al. 2015). Information gathered by researchers show that angel sharks, the most popular shark species for recreational divers, are incidentally caught by recreational and artisanal fishers (Barker et al., 2016). A study found that sharks and rays composed roughly 38% of total catch in weight in artisanal trammel net fisheries, of which angel shark represented more than 50% (Duran et al., 2018). Moreover, the increasing fishing effort from recreational fisheries, as a result of the excessive number of active licenses and unreported catches, suggests this sector has a strong negative impact on angel shark populations (Couce-Montero et al., 2015).

Although there has been a decrease of the shark catches in Macaronesia since 2011 and signs of stabilization in the last decade, the lack of effective monitoring, management and surveillance to improve catch reporting, halt overfishing and poaching represent major threats for shark populations in the region (Pramod et al. 2006; Hareide et al., 2007; Oceana, 2009; Carneiro, 2012; Pham et al., 2013; Castro 2014; Lehr, 2015; Correia et al., 2016; Torres et al., 2016). The fishing pressure coupled with the intrinsic vulnerability of some shark species makes urgent the need for more effective shark conservation measures (Hareide et al., 2007). Torres et al. (2017) stressed that decision makers should ensure that shark fishing is sustainable implementing comprehensive management plans in the region; however, in practice this objective is far from achievable in most places around the world (Ferretti et al., 2020). Moreover, as new shark-diving sites are discovered and advertised, there is some evidence that these areas can become a target for the exploitation of sharks, e.g. bull sharks in Mexico or Caribbean Reef sharks in the Bahamas (Gallagher et al., 2015).

4.3. Conservation potential of shark-diving tourism in the Macaronesian archipelagos

Despite yet not fully quantified for all the archipelagos in Macaronesia, the socioeconomic revenues of shark-diving tourism may present a robust argument for enhancing shark conservation policies in the region. For example, in the Azores 1,101 t of sharks and rays catches were landed in 2014 with a total landed value estimated in USD $ 8.2 million (Sea Around Us, 2021). This value represented around four times the total economic value of the Azorean shark-diving industry in the same year (USD $ 2.2 million, Torres et al., 2017). However, the total landed value of blue shark and shortfin mako shark in the Azorean local market was estimated to be over USD $ 20,000 (Torres et al., 2016). This suggests that most of the revenues from shark catches were captured by distant-water fleets, and that this industry

brings little economic benefits locally when compared to the local emerging shark diving industry that rely on the same pelagic species. With the potential expansion of the shark-diving industry in Macaronesia, this activity could generate comparable annual revenues to those yielded by shark fisheries, with potentially larger benefits for the local economy and community, as it has been demonstrated elsewhere (Vianna et al. 2012). In 2014, for example, the Azores received 1,280 tourists to engage in shark-diving activities (Torres et al., 2017). Assuming the average tourist expenditure estimated in Torres et al. (2017) remains the same and similar shark landings over time, a four-fold increase in the Azorean shark-diving industry would potentially result in larger annual revenues than the total landed value of sharks and rays fished within Archipelago. However, the widespread overfished status and severe declines of oceanic shark populations (Pacoureau et al., 2021) will inevitably result in decrease in catches in the near future, also potentially reducing the overall landed value and revenues from fishing sharks. Thus, alternative non-consumptive uses of shark populations, such as shark-diving tourism, should be preferred from a socio-economic and conservation perspective and is likely to increasingly represent an attractive strategy.

Direct revenues, income and employment generated directly and indirectly through shark-diving industry have influenced a shift in the socio-economic importance of sharks from fisheries products to non-consumptive resource in many tourist destinations around the world (Vianna et al., 2012; Brunnschweiler 2010; Gallagher et al., 2015). Further, the financial benefits from shark-based tourism can promote the protection of sharks and/or their habitats through conservation strategies and management (Vianna et al., 2012, 2018). Indeed, the number of Marine Protected Areas (MPAs) around shark-diving locations is growing worldwide together with very large shark-specific marine reserves in countries where shark-diving tourism contributes significantly to the nation's GDP such as Palau or Bahamas (Vianna et al., 2012; Gallagher et al., 2015). Additionally, there is evidence that dive tourists are more willing to pay to support the enforcement of marine protected areas for shark conservation in dive destinations where they have experienced shark-diving activities (Torres et al., 2017; Haas et al., 2017; Vianna et al., 2018).

Marine Protected Areas are a widely used tool for the protection of biodiversity and are increasingly advocated as a strategy for protecting or restoring shark and ray populations worldwide (Davidson & Dulvy, 2017; Ward-Paige, 2018, Gallagher et al. 2020). However, given some of the shark species found in the Macaronesian waters are highly migratory, MPAs would likely only protect individuals for part of their life cycle (Abecasis et al., 2015). According to Hernandez (2010), a larger-scale conservation plan including the entire main corridor of the Canary Current, from the Azores to Cape Verde, as a great sanctuary for highly migratory oceanic species is feasible. As an example, The Ligurian Sea Sanctuary, based on an agreement between three states and including areas located outside the respective national jurisdictions, is a marine sanctuary based on an international agreement (Carrillo & Marin, 2010). Considering the rapid decline of many shark populations in the North Atlantic (Worm et al., 2013; Dulvy et al., 2014) and signs of significant overfishing in the Canary Current Marine Ecoregion (Link et al., 2020), supra-regional control measures could be implemented to reduce shark-fishing mortality. A similar call for regional MPAs to protect highly-migratory species was recently announced in the Caribbean, which shares many similarities in terms of regional connectivity as the Macaronesian Region (Gallagher et al. 2020).

Shark-diving tourism may also serve as a potential instrument and platform for the implementation of citizen science initiatives to improve monitoring and understanding of shark populations in the region (Gallagher et al., 2015). Recreational scuba divers in the Canary Islands, for example, collaborated with researchers for assessing the abundance and distribution of angel sharks in the archipelago through registering their encounters with this

critical endangered species (Meyers et al., 2017). According to Azorean dive operators, dive companies consistently share information about shark encounters with the Department of Oceanography and Fisheries (DOP) at University of Azores since both target the same species (i.e., blue sharks). This cooperation allows them to better understand the areas where sharks can be found generating mutual benefits. Furthermore, shark-based tourism operations and marine science expeditions can also serve as deterrents for illegal or environmentally harmful activities such as poaching (Gallagher et al., 2015).

Although shark-diving tourism has proved to be a potential driver of conservation benefits, it is worth considering its limitations. While many studies have shown the financial contribution of shark-diving industry to several regions (Topelko & Dearden, 2005; Gallagher & Hammerschlag, 2011; Vianna et al 2011; Haas et al., 2017; Huveneers et al., 2017; Mieras et al., 2017; Zimmerhackel et al., 2019), economic estimations may be inaccurate (Brunnschweiler & Ward-Paige, 2014) or based on limited information (e.g., De la Cruz et al., 2010). Also, the shark-diving tourism industry focuses only on a limited number of species, while more than a hundred species are threatened with an elevated risk of extinction (Dulvy et al., 2014). Furthermore, shark conservation can still occur without the advent of shark-diving tourism, while the latter relies on the creation and enforcement of appropriate management regimes and the provision of alternative sources of income to local communities (Zimmerhackel et al., 2018).

4.4. Challenges for the potential expansion of shark-diving tourism in the Macaronesian archipelagos

Since a large number of shark encounters in Macaronesia are opportunistic in nature, a basic understanding of shark movement patterns and behavior from the region is required (Topelko & Dearden, 2005). As highly migratory species move seasonally, shark-diving operations could only occur for a few months per year, therefore the annual benefits of a shark-diving industry based on these species would be lower than those aggregated for longer periods. Providing a significant fraction of conservation incentives to local fisher communities against this backdrop seems to be more difficult to achieve (Cisneros-Montemayor et al., 2013). A regular payment throughout the year, potentially subsidized by governments, would be necessary if tourism can prove to be an essential activity for socioeconomic development.

Establishing a large-scale conservation plan for highly migratory species may contribute to the expansion of the shark-diving industry in Macaronesia. However, this would require a cohesive management strategy across the countries involved with individual jurisdictional and management requirements, which could present a significant challenge. In order to promote and achieve this vision, a shark conservation agenda would need to be included in the Summit of the Archipelagos of Macaronesia. This biannual meeting was formed in 2010 through a joint declaration of the State governments of Cape Verde, Spain, Portugal and the regional governments of the Azores, Canary Islands and Madeira, to foster a common approach to global challenges such as preservation and protection of the marine environment and tourism development (Menini et al., 2018). The Marine and Maritime Cluster of Macaronesia is another platform that could also be used to coordinate a set of protective measures targeting oceanic and coastal sharks and the regional expansion of the shark-diving industry. This joint action program formed by institutional, business and scientific-technological actors of the Macaronesian archipelagos is focused on fostering the sustainable economic growth and employment in the maritime sector of the Atlantic Ocean area of Macaronesia (Menini et al., 2018).

Conflicts between dive operators and local population in Cape Verde and legal barriers established by local authorities in the Canary Islands were reported by dive operators. In the Canary Islands this could be partially explained by the lack of public awareness of ecological benefits and economic inclusion from shark-diving tourism. Hence, a higher dissemination of the potential benefits of establishing a shark-diving industry would be necessary. In Cape Verde, for example, all companies were exclusively run by foreigners, thus the lack of incentive for the local communities to engage with the industry represents a challenge and needs to be addressed. Gallagher et al. (2015) have contended that in cases where community-based management is not in place, there is higher potential for poaching and resistance to the shark-diving industry from the local communities. Encouraging local communities in Cape Verde to have a leading role in the potential shark-diving industry could ensure that the business revenues generated may be translated into important socio-economic benefits (e.g. Pine et al., 2007; Pasos-Acuña et al., 2020).

Finally, any growth of the shark-diving industry in Macaronesia needs to be regulated and monitored to assure minimal negative impact to the marine life, habitats but also to the local human communities. For example, the coastal angel sharks are critically endangered species, as such diving operations targeting these sharks in the Canary Islands follows guidelines that aim to reduce the impact on the animals and that have been established in collaboration by local operators, marine scientists, managers and community. For oceanic sharks such as blue sharks or mako sharks, chumming may provide the only alternative for reliable encounters in Macaronesia, thus guidelines and regulations of this practice need to be particularly robust and enforced to assure safety of divers and well-being of the animals. In the Azores, the shark-diving industry is already limited to legally defined carrying capacities and codes of conduct established by the Regional Government in 2012 (Bentz et al., 2014), which are broadly followed by tourism operators (Afonso et al., 2020). With the potential development of the industry across Macaronesia these regulations need to be standardized in terms of restrictions across the archipelagos in order to ensure the coordinate management of shark-diving tourism and an effective regional cooperation for shark conservation.

5. Conclusions

Shark-diving tourism is considered to be a potential non-consumptive alternative of use of shark species. This industry, which can generate economic benefits for communities in different parts of the world, could be further developed in the Macaronesian archipelagos. However, the primary species targeted by the diving industry are also threatened by commercial and recreational fisheries. In particular, pelagic and migratory species overlap with Spanish and Portuguese industrial fisheries across all Macaronesian waters, while coastal species are being exploited by recreational and artisanal fisheries in the Canary Islands and Cape Verde. Although there may be some small operations that can persist on a local level, developing a robust industry that can provide incentives to local fishers for supporting diving activities requires to establish a regional policy to safeguard sharks. Increasing public awareness of the importance of sharks for ocean health, and, most critically – disseminating the ecological and economic benefits of shark-diving operations to local authorities of each archipelago is the first stage in this process. It is also necessary to strengthen management and effective monitoring of shark (and fisheries in general) catches by local and foreign fleets operating in the Macaronesian waters, coupled with the creation of large-scale protected areas over the region.

Sharks are widely distributed throughout the world's oceans and therefore shark-diving tourism has a large potential for expansion. For those places who share a regional connectivity, the Macaronesia could provide a comparable case study as there are different levels of industry development between the archipelagos. Nevertheless, the recognized potential benefits of shark-diving tourism are not directly applicable to all coastal destinations; therefore, a prior assessment of the potential benefits that may result from establishing a shark-diving industry in specific locations is essential for achieving sustainable and socio-economic goals.

Further research is needed to obtain more clarity on the potential for long-term benefit of shark-diving activities in Macaronesia. To accomplish this, the most important knowledge gaps needing filling are data on the abundance and distribution of shark populations in the Macaronesian waters, socioeconomic valuations of the potential shark-diving industry in each archipelago, updated data on the shark fisheries from North-East Atlantic to the Central-East Atlantic Ocean, and assessments of the local communities' perceptions and social inclusion in the shark-diving tourism industry.

References

Abecasis, R. C., Afonso, P., Colaço, A., Longnecker, N., Clifton, J., Schmidt, L., & Santos, R. S. (2015). Marine conservation in the Azores: evaluating marine protected area development in a remote island context. Frontiers in Marine Science, 2, 104.

Afonso, P., McGinty, N., & Machete, M. (2014) Dynamics of Whale Shark Occurrence at Their Fringe Oceanic Habitat. PloS ONE 9(7): e102060. Doi:10.1371/journal.pone.0102060

Afonso, P., Vandeperre, F., Fontes, J., & Porteiro, F. (2014). Conservation of Pelagic Elasmobranchs in the Azores. Pp. 25-30 in: Carreira, G., F. Cardigos & F.M. Porteiro (Eds). The sea of the Azores: scientific forum for decision support. Arquipelago. Life and Marine Sciences. Supplement 8.

Afonso, P., Fontes, J., Giacomello, E., Magalhães, M. C., Martins, H. R., Morato, T., Neves, V., Prieto, R., Santos, R. S., Silva, M. A. & Vandeperre, F. (2020). The Azores: a mid-Atlantic hotspot for marine megafauna research and conservation. Frontiers in Marine Science, 6, 826.

Aires-da-Silva, A. M., & Gallucci, V. F. (2007). Demographic and risk analyses applied to management and conservation of the blue shark (Prionace glauca) in the North Atlantic Ocean. Marine and Freshwater Research, 58(6), 570-580.

Aires-da-Silva, A., Ferreira, R. L., & Pereira, J. G. (2008). Case study: Blue shark catch-rate patterns from the Portuguese swordfish longline fishery in the Azores. Sharks of the open ocean: biology, fisheries and conservation, 230-235.

Azevedo F. (2017). European Parliament, Outermost Regions (Ors). Factsheets of the European Union, p.1– 3.

Barker, J., Bartoli, A., Clark, M., Dulvy, N.K., Gordon, C., Hood, A., Alvarado, D.J., Lawson, J. & Meyers, E. (2016). Angel shark Action Plan for the Canary Islands. ZSL.

Barreiros, J. P., & Gadig, O. B. (2011). Catálogo ilustrado dos tubarões e raias dos Açores. Catálogo ilustrado dos Tubarões, e Raias dos Açores= Sharks and Rays from the Azores: an illustrated catalogue.

Barreiros, J. P., Gadig, O. B., & Haddad, V. (2014). An unprovoked attack by a blue shark Prionace glauca (Chondrichthyes: 51xploitation5151) on a spear fisherman in Terceira Island, Azores, Northeast Atlantic. Wilderness & environmental medicine, 25(3), 371-372.

Benchimol, C., Francour, P., & Lesourd, M. (2009). The preservation of marine biodiversity in West Africa, the Case of Cape Verde Islands: proposal of a new biodiversity policy management. In 1st Cape Verde Congress of Regional Development, Praia, Santiago Island, Cape Verde. APDR (pp. 297-318).

Bentz, J., Dearden, P., & Calado, H. (2013). Strategies for marine wildlife tourism in small islands–the case of the Azores. Journal of coastal research, 65(sp1), 874-879.

Bentz, J., Dearden, P., Ritter, E., & Calado, H. (2014). Shark-diving in the Azores: challenge and opportunity. Tourism in Marine Environments, 10(1-2), 71-83.

Bentz, J., Rodrigues, A., Dearden, P., Calado, H., & Lopes, F. (2015). Crowding in marine environments: Divers and whale watchers in the Azores. Ocean & Coastal Management, 109, 77-85.

Brunnschweiler, J. M. (2010). The Shark Reef Marine Reserve: a marine tourism project in Fiji involving local communities. Journal of Sustainable Tourism, 18(1), 29-42.

Brunnschweiler, J. M., & Ward-Paige, C. A. (2014). Shark fishing and tourism. Oryx, 48(4), 486-487.

Calado, H., Ng, K., Lopes, C., & Paramio, L. (2011). Introducing a legal management instrument for offshore marine protected areas in the Azores—The Azores Marine Park. Environmental science & policy, 14(8), 1175-1187.

Carneiro, G. (2012). They Come, They Fish, and They Go: EC Fisheries Agreements with Cape Verde and São Tomé e Príncipe. Marine Fisheries Review, 73(4), pp. 1-25.

Carrillo, M. & Marin, C. (2010). La Macaronesia, un Área Marina Protegida para los mamíferos marinos. In: Almunia, C. M. J. Iniciativa Macaronesia – West African talks on Cetaceans and their habitat. Centro UNESCO de Canarias, 2010.

Carvalho, N., Edwards-Jones, G., & Isidro, E. (2011). Defining scale in fisheries: small versus large-scale fishing operations in the Azores. Fish. Res., 109, pp. 360-369, 10.1016/j.fishres.2011.03.006

Castro, J.J. (2014). Estado de Sobrepesca en Las Islas Canarias. Gonzalo Pérez-Rosales Blanch. Facultad de Ciencias Del Mar, Universidad de Las Palmas de Gran Canaria.

Castro, J. J., Divovich, E., Delgado de Molina Acevedo, A., & Barrera-Luján, A. (2015). Over-looked and under-reported: A catch reconstruction of marine fisheries in the Canary Islands, Spain, 1950-2010. Fisheries Centre: The University of British Columbia.

Cater, C. (2008). Perceptions of and Interactions with Marine Environments: Diving Attractions from Great Whites to Pygmy Seahorses in Garrod B. and Geossling S.(Eds.). New frontiers in marine tourism: diving experiences, sustainability, management.

Cisneros-Montemayor, A. M., Barnes-Mauthe, M., Al-Abdulrazzak, D., Navarro-Holm, E., & Sumaila, U. R. (2013). Global economic value of shark ecotourism: implications for conservation. Oryx, 47(3), 381-388.

Chen, V. Y., & Phipps, M. J. (2002). Management and trade of whale sharks in Taiwan. TRAFFIC East Asia-Taipei.

Coelho, R., Macías, D., Ortiz Urbina, J., Martins, A., Monteiro, C., Bach, P., Murua, H., Clark, J., Rosa, D., & Abaunza, P. (2017). The provision of advice on the conservation of pelagic sharks associated to fishing activity under EU Sustainable Fisheries Partnership Agreements in the Atlantic Ocean. Final Report. Specific Contract No. 7 under Framework Contract No. MARE/2012/21. 176 pp.

Correia, J. P., & Smith, M. F. (2003). Elasmobranch landings for the Portuguese commercial fishery from 1986 to 2001. Marine Fisheries Review, 65(1), 32-40.

Correia, J. P., Morgado, F., Erzini, K., & Soares, A. M. (2016). Elasmobranch landings in the Portuguese commercial fishery from 1986 to 2009. Arquipélago-Life and Marine Sciences, 33, 81-109.

Couce-Montero, L., Christensen, V., & Castro, J. J. (2015). Effects of small-scale and recreational fisheries on the Gran Canaria ecosystem. Ecological Modelling, 312, 61-76.

Couce Montero, L., Bilbao Seyro, A., Perez Gonzalez, Y., Abramic, A., & Castro Hernández, J. J. (2019). Analysis of the professional fishing sector in Macaronesia under MSFD. Finding the Balance of Blue Growth Sustainable Development within Ecosystem Approach (Act. 2.1.1 c&d). GMR Canarias, S.A.U. & ECOAQUA-ULPGC. Report prepared as part of PLASMAR Project (co-financed by ERDF as part of POMAC 2014-2020). 120 pp.

Das, D., & Afonso, P. (2017). Review of the diversity, ecology, and conservation of elasmobranchs in the Azores region, mid-north Atlantic. Frontiers in Marine Science, 4, 354.

Davidson, L. N., & Dulvy, N. K. (2017). Global marine protected areas to prevent extinctions. Nature ecology & evolution, 1(2), 1-6.

De la Cruz Modino, R., Esteban, A., Crilly, R., & Pascual-Fernandez, J. (2010). Bucear con tiburones y rayas en Espana. Analisis de su potencial en Espana y en las Islas Canarias., Instituto Universitario de Ciencias Politicas y Sociales NEF-The New Economics Foundation, 8-16.

De la Cruz Modino, R. (2011). The research about tourism viewing of sharks and rays in Spain. PASOS: Revista de Turismo y Patrimonio Cultural, 9(2), 467-476.

Dent, F., & Clarke, S. (2015). State of the global market for shark products. FAO Fisheries and Aquaculture technical paper, (590), I.

Diop, M. & Dossa, J. (2011) 30 Years of shark fishing in West Africa. Corlet/ Condé-sur-Noireau (France): Fondation 53xploitation53 du Bassin d'Arguin, Regional Marine and Coastal Conservation Programme for West Africa, and the Sub-Regional Fishing Commission.

Dive-Report (2016). Diving Sal. Available at http://www.divereport.com/ locations/53xploi/cape-verde/sal (accessed 10 January 2016).

Dulvy, N. K., Fowler, S. L., Musick, J. A., Cavanagh, R. D., Kyne, P. M., Harrison, L. R., Carlson, J. K., Davidson, L. N. K., Fordham, S. V., Francis, M. P., Pollock, C. M., Simpfendorfer, C. A., Burgess, G. H., Carpenter, K. E., Compagno, L. J. V., Ebert, D. A., Gibson, C., Heupel, M. R., Livingstone, S. R., Sanciangco, J. C., Stevens, J. D., Valenti, S. & White, W. T. (2014). Extinction risk and conservation of the world's sharks and rays. Elife, 3, e00590.

Dulvy, N. K., Simpfendorfer, C. A., Davidson, L. N., Fordham, S. V., Bräutigam, A., Sant, G., & Welch, D. J. (2017). Challenges and priorities in shark and ray conservation. Current Biology, 27(11), R565-R572.

Duran, J. C. M., Dorta, C., Brito, A., & Hernández, J. C. (2018). Elasmobranch Bycatch on Artisanal Trammel Net Fishery in the Canary Islands. Scientia Insularum-Islands Science, 1(1), 87-102.

EU Commission (2016). Report from the Commission to the European Parliament and the Council on the operation of Council Regulation (EC) No 1185/2003 on the removal of fins of sharks on board vessels, as amended by Regulation (EU) No 605/2013, and on the international developments in this field. 53xploitat in: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM:2016:207:FIN

EU Commission (2017). European Commission-Executive Agency for Small and Medium-sized Enterprises (EASME). Realising the potential of the Outermost Regions for sustainable blue growth. Final report.

Evans, P. (2010). Espacios Marinos Protegidos para Cetáceos: Sugerencias de Buenas Prácticas. In: Almunia, C. M. J. Iniciativa Macaronesia – West African talks on Cetaceans and their habitat. Centro UNESCO de Canarias, 2010.

Fauconnet, L., Pham, C., Canha, A., Afonso, P., Diogo, H., Machete, M., Silva, M.A., Vandeperre, F. & Morato, T. (2019). An overview of fisheries discards in the Azores. Fisheries research, 209, 230-241.

Ferretti, F., Jacoby, D. M., Pfleger, M. O., White, T. D., Dent, F., Micheli, F., Rosenberg, A., Crowder, L. & Block, B. A. (2020). Shark fin trade bans and sustainable shark fisheries. Conservation Letters.

Fontes, J., McGinty, N., Machete, M., & Afonso, P. (2016). Whale sharks, tunas and Azorean fisherman, BFF?. In The 4th International Whale Shark Conference (Vol. 2016, No. 2, p. 17). Hamad bin Khalifa University Press (HBKU Press).

Fowler, S., & Séret, B. (2010). Shark fins in Europe: Implications for reforming the EU finning ban. Simon Fraser University, IUCN Shark Specialist Group c/o Department of Biology.

Freitas M., Costa L., Delgado J., Jiménez S., Timóteo V., Vasconcelos J., & González J.A. (2018). Deep-sea sharks as by-catch of an experimental fishing survey for black scabbardfishes (Aphanopus spp.) off the Canary Islands (NE Atlantic). Sci. Mar. 82S1: 151-154. https://doi.org/10.3989/scimar.04793.03A

Gallagher, A. J., & Hammerschlag, N. (2011). Global shark currency: the distribution, frequency, and economic value of shark ecotourism. Current Issues in Tourism, 14(8), 797-812.

Gallagher, A. J., Vianna, G. M., Papastamatiou, Y. P., Macdonald, C., Guttridge, T. L., & Hammerschlag, N. (2015). Biological effects, conservation potential, and research priorities of shark-diving tourism. Biological Conservation, 184, 365-379.

Gallagher, A. J., Amon, D. J., Bervoets, T., Shipley, O. N., Hammerschlag, N., & Sims, D. W. (2020). The Caribbean needs big marine protected areas. Science, 367(6479), 749-1.

Gibson, C., Valenti, S. V., Fowler, S. L., & Fordham, S. V. (2008). The conservation status of Northeast Atlantic chondrichthyans. Report of the IUCN Shark Specialist Group Northeast Atlantic Red List Workshop; p. 76.

Gobierno de Canarias (2015). Estudio de Impacto Económico del Turismo: IMPACTUR Canarias 2014. Descargado de: http://www.Exceltur.Org/wp-content/uploads/2015/06/IMPACTUR-Canarias-2014. Pdf.

Goulding, I. & Stobberup, K. (2015). Pelagic Fisheries and the Canning Industry in Outermost Regions. European Parliament, Directorate-General for Internal Policies Policy Department B: Structural and Cohesion Policies. DOI: 10.13140/RG.2.1.3644.4646.

Goulding, I., & Lda, M. (2016). Research for PECH committee-Impact of fisheries partnership Agreements on employment in the EU and in third countries. European Parliament's Committee on Fisheries. Brussels: European Commission.

Haas, A. R., Fedler, T., & Brooks, E. J. (2017). The contemporary economic value of elasmobranchs in The Bahamas: Reaping the rewards of 25 years of stewardship and conservation. Biological conservation, 207, 55-63.

Hareide, N. R., Carlson, J., Clarke, M., Clarke, S., Ellis, J., Fordham, S. Fowler, S., Pinho, M., Raymakers, C., Serena, F., Seret, B. & Polti, S. (2007). European Shark Fisheries: a preliminary investigation into fisheries, conversion factors, trade products, markets and management measures. European Elasmobranch Association, 1-57.

Hernández, A. B. (2010). Biogeografía y conservación de la biodiversidad marina en la Macaronesia. INICIATIVA, 97.

Huveneers, C., Meekan, M. G., Apps, K., Ferreira, L. C., Pannell, D., & Vianna, G. M. (2017). The economic value of shark-diving tourism in Australia. Reviews in Fish Biology and Fisheries, 27(3), 665-680.

ICES – International Council for the Exploration of the Sea. (2018). EU request for ICES to provide advice on a revision of the contribution of TACs to fisheries management and stock conservation for selected deep-water stocks. ICES Special Request Advice North Atlantic ecoregions Published 2 July 2018. 10.17895/ices.pub.4493.

IUCN-International Union for Conservation of Nature. (2013). The IUCN Red List of Threatened Species. Version 2013.2.

Lehr, H. (2015). Traceability study in shark products. Report prepared for the CITES Secretariat.

Link, J. S., Watson, R. A., Pranovi, F., & Libralato, S. (2020). Comparative production of fisheries yields and ecosystem overfishing in African Large Marine Ecosystems. Environmental Development, 100529.

Lopes, K., Passos, L., Rodrigues, J. G., Koenen, F., Stiebens, V., Székely, T., & Dutra, A. (2016). Sea Turtle, Shark, and Dolphin Bycatch Rates by Artisanal and Semi-Industrial Fishers in Maio Island, Cape Verde. Chelonian Conservation and Biology, 15(2), 279-288.

Madruga L., Wallenstein F., Azevedo J.M.N (2016). Regional ecosystem profile–Macaronesian Region. EU Outermost Regions and Overseas Countries and Territories. BEST, Service contract 07.0307.2013/666363/SER/B2, European Commission, p. 1– 324.

Menini, E., Halim, F., Gabriel, D., Suarez de Vivero, J. L., Calado, H., Moniz, F., & Caña Varona, M. (2018). Geopolitical framework of the Macaronesia region. This project was financed in, 85, 3.

Meyers, E. K., Tuya, F., Barker, J., Jimenez Alvarado, D., Castro-Hernández, J. J., Haroun, R., & Rödder, D. (2017). Population structure, distribution and habitat use of the Critically Endangered Angelshark, Squatina squatina, in the Canary Islands. Aquatic Conservation: Marine and Freshwater Ecosystems, 27(6), 1133-1144.

Mieras, P. A., Harvey-Clark, C., Bear, M., Hodgin, G., & Hodgin, B. (2017). The economy of shark conservation in the Northeast Pacific: the role of ecotourism and citizen science. In Advances in marine biology (Vol. 78, pp. 121-153). Academic Press.

Morato, T. (2012). Description of environmental issues, fish stocks and fisheries in the EEZs around the Azores and Madeira. Report for the European Commission, Directorate-General Maritime Affairs and Fisheries, B-1049 Brussels, Belgium. Available online at: https://stecf. Jrc. Ec. 55xploi. Eu/documents/43805/465474/Item, 6.

Morey, G, Barker, J., Hood, A., Gordon, C., Bartolí, A., Meyers, E.K.M., Ellis, J., Sharp, R., Jimenez-Alvarado, D., & Pollom, R. 2019. Squatina squatina. The IUCN Red List of Threatened Species 2019: e.T39332A117498371. https://dx.doi.org/10.2305/IUCN.UK.2019-1.RLTS.T39332A117498371.en.

Narvaez, K. (2013). Aspectos biológicos y ecológicos del tiburón ángel Squatina squatina (Linnaeus 1758) en la isla de Gran Canaria (PhD thesis). University of Las Palmas de Gran Canaria, Spain.

Nieto, A., Ralph, G.M., Comeros-Raynal, M.T., Kemp, J., García Criado, M., Allen, D.J., Dulvy, N.K., Walls, R.H.L., Russell, B., Pollard, D., García, S., Craig, M., Collette, B.B., Pollom, R., Biscoito, M., Labbish Chao, N., Abella, A., Afonso, P., Álvarez, H., Carpenter, K.E., Clò, S., Cook, R., Costa, M.J., Delgado, J., Dureuil, M., Ellis, J.R., Farrell, E.D., Fernandes, P., Florin, A-B., Fordham, S., Fowler, S., Gil de Sola, L., Gil Herrera, J., Goodpaster, A., Harvey, M., Heessen, H., Herler, J., Jung, A., Karmovskaya, E., Keskin, C., Knudsen, S.W., Kobyliansky, S., Kovačić, M., Lawson, J.M., Lorance, P., McCully Phillips, S., Munroe, T., Nedreaas, K., Nielsen, J., Papaconstantinou, C., Polidoro, B., Pollock, C.M., Rijnsdorp, A.D., Sayer, C., Scott, J., Serena, F., Smith-Vaniz, W.F., Soldo, A., Stump, E., & Williams, J.T. (2015). European Red List of marine fishes. Luxembourg: Publications Office of the European Union.

Nshimyumuremyi, A. (2018). African Economic Outlook Country Note, Cabo Verde.

Oceana (2007). Perseguidos por sus aletas: Cómo las flotas de la UE pescan tiburones en peligro – sin 55xploit – en los océanos del mundo. Mayo 2017, 15 pp.

Oceana (2009). Description of the European Union surface longline fleet operating in the Atlantic Ocean and compilation of detailed EUROSTAT data on shark catches by EU fleets in the Atlantic. ICCAT, Collective Volume of Scientific Papers, 64, 1746–1754.

Ojamaa, P. 2015. 'Fisheries in Azores'. European Parliament. http://www.europarl.europa.eu/RegData/etudes/STUD/2015/540355/IPOL_STU(2015)540355_EN.pdf.

Oliveira, M. T. C. L. D. (2016). The role of artificial reefs to promote biodiversity and sustainability of the ecotourism in Cape Verde: ecological, biological and management aspects.

Pacoureau, N., Rigby, C. L., Kyne, P. M., Sherley, R. B., Winker, H., Carlson, J. K., Fordham, S. V., Barreto, R., Fernando, D., Francis, M. P., Jabado, R. W., Herman, K. B., Liu, K., Marshall, A. D., Pollom, R. A., Romanov, E. V., Simpfendorfer, C., A., Yin, J. S., Kindsvater, H. K. & Dulvy, N. K. (2021). Half a century of global decline in oceanic sharks and rays. Nature, 589(7843), 567-571.

Pasos-Acuña, C., Almendarez-Hernández, M. A., Hoyos-Padilla, E. M., Blázquez, M. C., & Ketchum, J. T. (2020). Economic Valuation of Diving with Bull Sharks in Natural Conditions: A Recent Activity in Cabo Pulmo National Park, Gulf of California, Mexico. In Socio-ecological Studies in Natural Protected Areas (pp. 485-509). Springer, Cham.

Pauly, D., Christensen, V., Guenette, S., Pitcher, T., Sumaila, R., Walters, C., Watson, R., & Zeller, D. (2002). Towards sustainability in world fisheries. Nature. 418. 689-95. 10.1038/nature01017.

Perrotta, R. G. (2004). Kitefin shark Dalatia licha (Dalatiidae) fishery in the northeastern Atlantic and some recommendations for elasmobranchs 56xploitation. Revista de Investigación y Desarrollo Pesquero, 16, 97-101.

Pham, C. K., Canha, A., Diogo, H., Pereira, J. G., Prieto, R., & Morato, T. (2013). Total marine fishery catch for the Azores (1950–2010). ICES Journal of Marine Science, 70(3), 564-577.

Pine, R., Alava, M. N. R., & Yaptinchay, A. A. (2007). Challenges and lessons learned in setting-up a community-based whale shark eco-tourism program: the case in Donsol, Philippines. In The first international whale shark conference: promoting international collaboration in whale shark conservation, science and management. Conference overview, abstracts and supplementary proceedings (pp. 36-44). CSIRO Marine and Atmospheric Research: Wembley, Australia.

Pires, N. M., Garla, R. C., & Carvalho, A. R. (2016). The economic role of sharks in a major ecotourism archipelago in the western South Atlantic. Marine Policy, 72, 31-39.

Ponte, J., Couto, G., Pimentel, P. & Oliveira, A. (2018). Tourism activities and companies in a sustainable adventure tourism destination: the Azores. Tourism & Management Studies, 14(4), 25-38. DOI: https://doi.org/10.18089/tms.2018.14403

Pramod, G., Pitcher, T. J., Rojo-Diaz, P. & Kalikoski D (2006) An estimation of compliance of the fisheries of Spain with Article 7 (Fisheries Management) of the FAO (UN) Code of Conduct for Responsible Fishing. Evaluations of compliance with the FAO (UN) Code of Conduct for Responsible Fisheries 14(2), Fisheries Centre Research Reports 26 p.

Queiroz, N., Humphries, N.E., Couto, A., Vedor, M., da Costa, I., Sequeira, A.M.M., Mucientes, G., Santos, A.M., Abascal, F.J., Abercrombie, D.L., Abrantes, K., Acuña-Marrero, D., Afonso, A.S., Afonso, P., Anders, D., Araujo, G., Arauz, R., Bach, P., Barnett, A., Bernal, D., Berumen, M.L., Bessudo Lion, S., Bezerra, N.P.A., Blaison, A.V., Block, B.A., Bond, M.E., Bonfil, R., Bradford, R.W., Braun, C.D., Brooks, E.J., Brooks, A., Brown, J., Bruce, B.D., Byrne, M.E., Campana, S.E., Carlisle, A.B., Chapman, D.D., Chapple, T.K., Chisholm, J., Clarke, C.R., Clua, E.G., Cochran, J.E.M., Crochelet, E.C., Dagorn, L., Daly, R., Devia Cortés, D., Doyle, T.K., Drew, M., Duffy, C.A.J., Erikson, T., Espinoza, E., Ferreira, L.C., Ferretti, F., Filmalter, J.D., Fischer, C.G., Fitzpatrick, R., Fontes, J., Forget, F., Fowler, M., Francis, M.P., Gallagher, A.J., Gennari, E., Goldsworthy, S.D., Gollock, M.J., Green, J.R., Gustafson, J.A., Guttridge, T.L., Guzman, H.M., Hammerschlag, N., Harman, L., Hazin, F.H.V., Heard, M., Hearn, A.R., Holdsworth, J.C., Holmes, B.J., Howey, L.A., Hoyos, M., Hueter, R.E., Hussey, N.E., Huveneers, C., Irion, D.T., Jacoby, D.M.P., Jewell, O.J.D., Johnson, R., Jordan, L.K.B., Jorgensen, S.J., Joyce, W., Keating Daly, C.A., Ketchum, J.T., Klimley, A.P., Kock, A.A., Koen, P., Ladino, F., Lana, F.O., Lea, J.S.E., Llewellyn, F., Lyon, W.S., MacDonnell, A., Macena, B.C.L., Marshall, H., McAllister, J.D., McAuley, R., Meÿer, M.A., Morris, J.J., Nelson, E.R., Papastamatiou, Y.P., Patterson, T.A., Peñaherrera-Palma, C., Pepperell, J.G., Pierce, S.J., Poisson, F., Quintero, L.M., Richardson, A., Rogers, P.J., Rohner, C.A., Rowat, D.R.L., Samoilys, M., Semmens, J.M., Sheaves, M., Shillinger, G., Shivji, M., Singh, S., Skomal, G.B., Smale, M.J., Snyders, L.B., Soler, G., soria, M., Stehfest, K.M., Stevens, J.D., Thorrold, S.R., Tolotti, M.T., towner, A., Travassos, P, tyminski, J.P., Vandeperre, F., Vaudo, J.J., Watanabe, Y.Y., Weber, S.B., Wetherbee, B.M., White, T.D., Williams, S., Zárate, P.M., Harcourt, R., Hays, G.C., Meekan, M.G., Thums, M., Irigoien, X., Eguiluz, V.M., Duarte, C.M., Sousa, L.L., Simpson, S.J., Southall, E.J., & Sims, D.W. (2019) Global spatial risk assessment of sharks under the footprint of fisheries. Nature, https://doi.org/10.1038/s41586-019-1444-4

Ramos, J., Oliveira, M. T., & Santos, M. N. (2011). Stakeholder perceptions of decision-making process on marine biodiversity conservation on Sal island (Cape Verde). Brazilian Journal of Oceanography, 59(SPE1), 95-105.

Ressurreição, A., & Giacomello, E. (2013). Quantifying the direct use value of Condor seamount. Deep Sea Research Part II: Topical Studies in Oceanography, 98, 209-217.

Rigby, C.L., Barreto, R., Carlson, J., Fernando, D., Fordham, S., Francis, M.P., Herman, K., Jabado, R.W., Liu, K.M., Marshall, A., Pacoureau, N., Romanov, E., Sherley, R.B., & Winker, H. (2019a).

Prionace glauca. The IUCN Red List of Threatened Species 2019: e.T39381A2915850. https://dx.doi.org/10.2305/IUCN.UK.2019-3.RLTS.T39381A2915850.en.

Rigby, C.L., Barreto, R., Carlson, J., Fernando, D., Fordham, S., Francis, M.P., Jabado, R.W., Liu, K.M., Marshall, A., Pacoureau, N., Romanov, E., Sherley, R.B., & Winker, H. (2019b). Isurus oxyrinchus. The IUCN Red List of Threatened Species 2019: e.T39341A2903170. https://dx.doi.org/10.2305/IUCN.UK.2019-1.RLTS.T39341A2903170.en.

Saavedra, J. M. (2011) Analysis of the state of fishery resources from Gran Canaria study of the historical catch series Master in Sustainable Management of Fisheries Resources thesis, University of University of Las Palmas de Gran Canaria, Marine Science, Las Palmas de Gran Canaria. 39 p.

Simpfendorfer, C. A., & Dulvy, N. K. (2017) Bright spots of sustainable shark fishing. Current Biology 27(3), R97-R98.

Stobberup, K. A., Ramos, V. D. M., & Coelho, M. L. (2004). Ecopath model of the Cape Verde coastal ecosystem. In West African Marine Ecosystems, MLD Palomares and D. Pauly.

Sutcliffe, S. R., & Barnes, M. L. (2018). The role of shark ecotourism in conservation behaviour: Evidence from Hawaii. Marine Policy, 97, 27-33.

Tavares, J. P. C. (2016). O Mergulho com Tubarões como produto turístico específico nos Açores (Master dissertation).

Topelko, K. N., & Dearden, P. (2005). The shark watching industry and its potential contribution to shark conservation. Journal of Ecotourism, 4(2), 108-128.

Torre, G., Fernández-Lugo, S., Guarino, R., & Fernández-Palacios, J. M. (2019). Network analysis by simulated annealing of taxa and islands of Macaronesia (North Atlantic Ocean). Ecography, 42(4), 768-779.

Torres, P., da Cunha, R. T., & dos Santos Rodrigues, A. (2016). The elasmobranch fisheries of the Azores. Marine Policy, 73, 108-118.

Torres, P., Bolhão, N., da Cunha, R. T., Vieira, J. A. C., & dos Santos Rodrigues, A. (2017). Dead or alive: The growing importance of shark-diving in the Mid-Atlantic region. Journal for nature conservation, 36, 20-28.

Torres, P. G. M. A. (2017). Elasmobranchii (sharks and rays), a potencial resource to protect in the Azores? Tese de doutorado, Universidade dos Açores –UAC.

Troëng and Drews, 2008. Money talks: a global economic valuation of marine turtles. NOAA Technical Memorandum NMFS SEFSC, no. 567, pp. 57, January, 2008

Vandeperre, F., Aires-da-Silva, A., Fontes, J., Santos, M., Santos, R. S., & Afonso, P. (2014). Movements of blue sharks (Prionace glauca) across their life history. PloS One, 9(8).

Vianna, G. M., Meeuwig, J. J., Pannell, D., Sykes, H., & Meekan, M. G. (2011). The socioeconomic value of the shark-diving industry in Fiji. Perth: University of Western Australia. 26p.

Vianna, G. M. S., Meekan, M. G., Pannell, D. J., Marsh, S. P., & Meeuwig, J. J. (2012). Socio-economic value and community benefits from shark-diving tourism in Palau: a sustainable use of reef shark populations. Biological Conservation, 145(1), 267-277.

Vianna, G. M., Meekan, M. G., Rogers, A. A., Kragt, M. E., Alin, J. M., & Zimmerhackel, J. S. (2018). Shark-diving tourism as a financing mechanism for shark conservation strategies in Malaysia. Marine Policy, 94, 220-226.

Wirtz, P., Brito, A., Falcón, J. M., Freitas, R., Fricke, R., Monteiro, V., Reiner, F. & Tariche, O. 2013. The coastal fishes of the Cape Verde Islands – new records and an annotated check-list (Pisces). Spixiana 36 (1): 113-142.

Worm, B., Davis, B., Kettermer, L., Ward-Paige, C.A., Chapman, D., Heithaus, M.R., Kessel S.T. & Gruber, S. H. (2013). Global catches, exploitation rates, and rebuilding options for sharks. Marine Policy, 40, 194-204.

Zimmerhackel, J. S., Rogers, A. A., Meekan, M. G., Ali, K., Pannell, D. J., & Kragt, M. E. (2018). How shark conservation in the Maldives affects demand for dive tourism. Tourism Management, 69, 263-271.

Zimmerhackel, J. S., Kragt, M. E., Rogers, A. A., Ali, K., & Meekan, M. G. (2019). Evidence of increased economic benefits from shark-diving tourism in the Maldives. Marine Policy, 100, 21-26.

CHAPTER 2

ECONOMIC IMPACT AND CONSERVATION POTENTIAL OF SHARK-DIVING TOURISM IN THE AZORES ISLANDS

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CHAPTER 2

Economic impact and conservation potential of shark-diving tourism in the Azores Islands

Abstract

Shark-diving tourism is an emerging industry in the Azores Islands. However, this industry directly competes with fishing, as both exploiting the same highly migratory shark species. This study quantifies the commercial value of the Azorean shark-diving industry based on a survey of dive tourists and local dive operators and the potential of this industry to further generate funds for implementation of direct conservation actions. The economic contribution of the shark-diving industry to the regional economy of the Azores in 2019 was estimated to be just over USD $ 1 Million. The results of a spiked censored interval data model of contingent valuation indicated that implementation of an extra conservation fee per dive trip, to be paid by dive tourists, could potentially yield over USD $ 103,000 per year to be used for management and enforcement of a proposed MPA for sharks around the dive sites. Our analysis suggests that the emerging shark-diving industry in the Azores Islands has potential to grow throughout the Macaronesian archipelago, thereby increasing tax revenues and the number of jobs and income to Azorean local communities, potentially promoting conservation and sustainable use of the shark populations. However, expansion of this industry into a robust contributor to the archipelago's economy would require a concomitant strengthening of industry regulation, and support by the government, to protect businesses and investments. This could be partially obtained through improving in fisheries management, implementation of a functional MPA and adequate enforcement.

Keywords: Shark-based tourism, Socio-economic valuation, Shark conservation, Willingness-to-pay, Wildlife tourism, North-East Atlantic

1. Introduction

The Azores is an increasingly popular destination for nature-based tourism, receiving more than 600,000 visitors each year (Azorean Statistical Office, 2017). Tourists are mainly attracted by the archipelago's landscapes and marine-related activities such as sailing, surfing, whale and dolphin watching and, more recently, scuba and shark diving (Calado et al., 2011). In the Azores shark diving is a summer season activity that began in 2011 (Bentz et al., 2014), growing in popularity among European tourists due to the reliability of encounters and quality of experience. The Azores has the only specialized shark-diving industry in the Macaronesian Region (Gonzáles-Mantilla et al., 2021), targeting pelagic shark species such as shortfin mako sharks (*Isurinus oxyrinchus*) and, primarily, blue sharks (*Prionace glauca*, Bentz et al., 2014). This industry was estimated to generate a total economic contribution of over USD $ 2 million in 2014 (Torres et al, 2017), and has shown signs of increasing demand over the last decade.

Observing sharks in their natural habitat using snorkel or scuba gear (from here on defined as shark diving) is an activity that is rapidly growing in popularity globally (Gallagher & Hammerschlag, 2011), with nearly 600,000 participants engaged in this industry each year (Cisneros-Montemayor et al., 2013). This type of non-consumptive use of sharks generates substantial benefits to local and regional economies in several countries through direct business revenues, regional and national taxes, jobs creation and indirect revenues to accessory services such as accommodation, food and transport (Topelko & Dearden, 2005; Vianna et al., 2011; Vianna et al., 2012; Haas et al., 2017; Huveneers et al., 2017; Mieras et al., 2017; Vianna et al., 2018; Zimmerhackel et al., 2019). For tropical island economies, which often rely on marine tourism as a major source of revenues, the contribution of the shark-diving industry can be considerable, and may account for an important fraction of their Gross Domestic Product (Vianna et al. 2012).

Contrastingly, many of the shark species on which shark-diving tourism industry relies on are exposed to unsustainable and unmanaged fisheries (Worm et al., 2013). In the Azorean waters, blue shark and shortfin mako shark are historically caught by-catch by European industrial longlines fisheries targeting swordfish (Torres et al., 2016; Das & Afonso, 2017; Santos et al., 2020). However, a recent global analysis found that industrial fishing activities in the North Atlantic have an 80% overlap with the space use of blue sharks and suggest that these species are now targeted (Queiroz et al., 2019). Despite certain shark fishing regulations, which have been established by the European Union forbidding the catch and trade of some shark species (e.g. hammerhead, thresher sharks or deep water sharks), and an overall ban on shark finning since 2003, catches of blue and shortfin mako shark in the Azores are still largely unregulated, leading to regional population declines (Worm et al., 2013; Campana, 2016; Torres et al., 2016).

Shark-diving tourism has, in certain contexts, played a key role in demonstrating a new paradigm for viewing sharks as a renewable, socio-economically valuable, and non-consumptive resource when compared to fishing (Vianna et al., 2010; Gallagher and Hammerschlag, 2011, Gallagher & Huveneers, 2018). The economic benefits brought by shark diving may provide strong incentives for the implementation of management strategies that seek to maintain healthy populations of sharks (Vianna et al., 2018). Globally, there is an increase in the number of Marine Protected Areas (MPAs) designated for sharks, as well as national-level conservation measures to prohibit sharks being caught and killed (e.g. shark sanctuaries), many of which appear to occur within key shark-diving destinations (Gallagher et al., 2015). These MPAs have been suggested as instruments for protecting or restoring shark

populations worldwide (Hoyt, 2014; Davidson & Dulvy, 2017; Ward-Paige, 2017, Gallagher et al. 2020). However, the displacement of fishing activities and resulting social impact caused by the implementation of these MPAs is a complex issue, driven by challenges around access to adequate resources for financial compensation to local communities, as well as those related to monitoring and surveillance to ensure the effectiveness of MPAs (Edgar et al., 2014; Worm, 2017).

To overcome some of the financial challenges of establishment and enforcement of shark-related MPAs, a sustainable financial option may include fee payments levied on tourists and operators engaging shark-diving trips. Previous studies have shown that dive tourists are often willing to pay to support the enforcement of MPAs for shark conservation in dive destinations where they have experienced shark-diving activities (Torres et al., 2017; Haas et al., 2017; Vianna et al., 2018). This mechanism has been suggested as a strategy to assist funding the effective implementation of conservation measures and to assist transition of local communities to sustainable activities integrated to the emerging shark-diving industry (Vianna et al. 2018)

1.1. Economic valuation of shark-diving tourism

Economic valuations have played an increasingly important role in shaping policy decisions regarding the conservation and management of wildlife, including sharks (Cazabon-Mannette et al., 2017; Gallagher et al., 2015). Although there are no reliable global measures of the economic impact of wildlife tourism (Higginbottom, 2004), a range of methods have been employed to estimate the total economic impact of this industry, from the consideration of the aggregated value of production through the volume of tour or access ticketing revenues, to the utilization of intersectoral macroeconomic impact modeling through Input Output Analysis (Catlin et al., 2013).

In the case of shark-diving tourism, socio-economic studies have been conducted at many scales, providing an overview of the contribution of shark-diving industry to regional and national economies (e.g. Dicken and Hosking, 2009; Clua et al., 2011; Vianna et al., 2011; Gallagher & Hammerschlag, 2011; Vianna et al., 2012; Cisneros-Montemayor et al., 2013; Pires et al., 2016; Torres et al., 2017; Haas et al., 2017; Huveneers et al., 2017; Mieras et al., 2017; Zimmerhackel et al., 2019). Industry-wide valuations and economic assessments are well established within the scientific literature; however, inconsistencies in methods among studies and time lags among estimates may limit the ability to compare and combine studies to provide global estimates for the industry (Gallagher et al., 2015).

In more recent years, standardized valuation methods have been used in several countries around the world. These valuation studies have quantified the direct and indirect expenditures of participants engaged in shark-diving, quantifying similar metrics to assess the economic impact of shark-diving tourism and benefits for the locations where the activity is established (e.g. Vianna et al., 2011; Vianna et al., 2012; Huveneers et al., 2017; Haas et al., 2017; Vianna et al., 2018; Mustika et al., 2020).

1.2. Contingent valuation

The contingent valuation method (CVM) is a non-market valuation approach commonly utilized to determine the "willingness to pay" (WTP) of individuals for the provision of non-market environmental goods or services, or for public policies that have not yet been implemented (Portney, 1994; Hanley et al., 2009; Hoyos & Mariel, 2010). Contingent valuation method studies have been successfully used in combination to shark-diving economic impact studies as a tool to investigate the potential established shark-diving operations may have to finance the implementation of shark conservation strategies in the absence of governmental financial support (Vianna et al., 2018). The CVM has also been used extensively to understand values associated with marine species conservation such as turtles (Whitehead, 1992; Stithou & Scarpa, 2012; Cazabon-Mannette et al., 2017), whales (Loomis and Larson, 1994; Ressurreição et al., 2012), manatees (Solomon et al., 2004), penguins (Lewis et al., 2012), and sharks (Arthur, 2011; Indab, 2016; Vianna et al., 2018).

Based on the utility maximization principle of welfare economics (Boyle, 2003), the CVM reveals respondents' WTP for hypothetical quality or quantity changes of marine tourism resources. Data collection is based on a survey questionnaire that poses individuals with a tradeoff between market and non-market values (Xiao et al., 2020). The CVM is a widely used technique which offers flexibility as it is capable of capturing all components of Total Economic Value (TEV) including use and non-use values; allows the valuation of environmental changes that have not yet occurred; provides a full socio-demographic profile of the target population; allows contingent scenarios to be designed to directly elicit the value of the change under scrutiny and allows a better alignment of public expectations and political initiatives as the valuation process is submitted to public discussion (Arrow et al., 1993).

However, CVM studies have been subject to some criticisms (Venkatachalam, 2004, White et al., 2001) due the potential emergence of some biases in the survey responses, such as hypothetical bias, information bias, protest response bias, elicitation format bias and scope effect (Frontuto et al., 2017; Ressurreição et al., 2012). For example, individual responses relying upon a hypothetical scenario, respondents may have less awareness of the proposed valuation and change of interests, and other biases associated with the selection of eliciting formats and the type of payment vehicles used (Carson, 2000). However, the CVM is generally recognized as a technique that can lead to sufficiently reliable estimates if specific guidelines or protocols are followed (Arrow et al., 1993). In particular, scholars need to be cautious about potential biases and try to control by employing adequate survey design, maintaining the adequacy of samples, developing a well-narrated hypothetical scenario, and employing appropriate eliciting formats and payment vehicles (e.g. Cazabon-Mannette et al., 2017; Vianna et al., 2018; Aseres & Sira, 2020). Thus, when adequately designed, CVM may offer useful insights of the potential of groups of respondents to provide financial support to specific conservation strategies, such as the creation and maintenance of MPAs (Vianna et al., 2018)

This study aims to assess the regional economic contribution of the shark-diving industry in the Azores Islands based on dive tourists' expenditure and its potential to finance shark conservation strategies through dive tourists' willingness to pay. We combined these two approaches to provide a more comprehensive understanding of the potential of the Azorean shark-diving industry for conservation of two commercially important oceanic shark species: blue and shortfin mako shark. Thus, we present a standardized and robust analysis of the socio-economic impact of the shark-diving industry in the Azores using survey data and provide an analysis on the potential of shark-diving tourism to assist financial support for the establishment of a shark-related marine protected area.

2. Methods

2.1. Study site

The Azores Islands is considered the most remote oceanic archipelago in the North Atlantic and is located about 1,600 kilometers from the west of mainland Portugal coast and 3,900 kilometers from the east coast of North America. It is one of the two autonomous regions of Portugal, together with Madeira, and accounts for over 2% of the Portuguese population (above 247,000 inhabitants). This archipelago encompasses an area of 2,333 km^2 and is formed by nine volcanic islands divided in 3 groups: The Eastern Group of São Miguel and Santa Maria, the Central Group of Terceira, Graciosa, São Jorge, Pico and Faial, and the Western Group of Flores and Corvo (Fig. 1).

The Azores is one of the outermost regions of Europe and faces specific social and economic challenges such as the remoteness, insularity, small size, changeable climate, economic dependence on a few products (Kaim, 2018) and the fragmentation and dispersion of its internal market (Couto et al., 2017). The current drivers of the Azorean economy are agriculture, agro-industries, fisheries and tourism (Dentinho & Fortuna, 2019). The latter has been seen by the Regional Government of the Azores as a strategic activity since the mid-1990s and public policies such as the expansion of accommodation capacity, international touristic promotion and airline liberalization have been adopted (Vieira et al., 2019).

2.2. Shark-diving tourism in the Azores Islands

Diving with sharks in the Azorean archipelago started experimentally in 2009-2010 with expeditions around Pico and Faial Islands seeking to explore the potential of this activity in the region (Ressurreição & Giacomello, 2013). However, it was not until 2011 that it began as an industry (Torres et al., 2017). Scuba-diving season lasts from June to October, during summer months, though shark-diving activities are mostly operated from July to September. According to Gonzáles-Mantilla et al. (2020), eight diving centers were conducting dedicated shark-diving operations in 2019 (over 13% of the total Azorean diving industry); however, four Azorean diving centers receive between 80-90% of the total number of shark-diving tourists in the region. These diving centers are established equally on Faial and Pico Islands, with two centers on each island (Fig. 1). Despite being partially foreign-owned, local workers are also engaged in the business as skippers, dive guides and general staff.

The blue shark is the main specie targeted by shark-diving operations in the Azores; however, shortfin mako shark may occasionally be observed. According to dive operators, the number of sightings of the latter has reduced compared to few years ago when this specie was sighed in roughly 30% of the shark-dive trips. There are mainly two shark-diving sites: Pedra de Sousa, located at seven nautical miles northeast from port of Horta, and Condor Bank, at 20 nautical miles southwest from the same port. Due to the remoteness of Condor Bank from the ports of Horta and Madalena (roughly three hours on vessel), most of the operations occur in Pedra de Sousa (less than one hour on vessel). The frequency and abundance of blue sharks vary in each dive site during the season, therefore diving centers maintain regular communication with the Department of Oceanography and Fisheries (DOP) of the University of the Azores at Horta exchanging information about the location with highest probability for shark sightseeing.

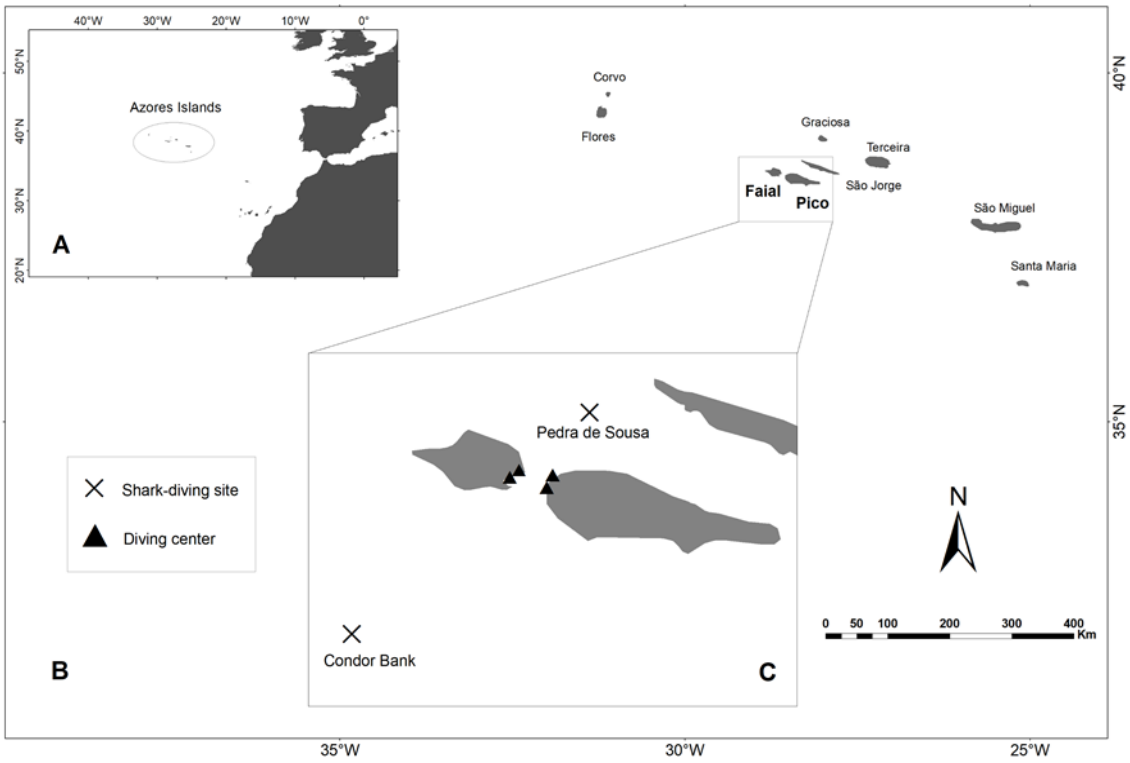

Fig. 1. (A) Geographic location of the Azores Islands, (B) Geographic location of Faial and Pico Islands in the Azores archipelago, (C) Location of shark-diving sites and the four main diving centers providing shark-diving operations in the Azores Islands.

Shark-diving operations in the Azores are conducted as half-day trips in offshore waters. Dive operators deploy a bait bucket containing a mixture of blood, tuna and cut sardines, to lure sharks to the vessel. The shark-diving trip may last between four and six hours, depending on how long it takes for the sharks to arrive (from 30 min to 3 hours). A maximum of eight dive tourists and one dive guide may enter the water under at a given time. Dives are performed in pelagic waters (sea floor at 200m) but to a maximum dive depth of 10 meters. All the operations are performed under the code of conduct established by the Regional Government of the Azores. This code, developed in 2012 between two regional secretaries (Tourism and Ocean), four operators, and the University of the Azores, addresses activity preparation, human safety, animal wellbeing, diver attitude, and miscellaneous concerns (Bentz et al., 2014).

The cost per shark-diving trip varies according to diver expertise and diving center ranging from € 175 (USD $ 194) to € 195 (USD $ 216). Whereas in Faial, the cost per dive ranges between € 165 (USD $ 183) and € 170 (USD $ 188). Faial diving centers also provided snorkeling with sharks with a cost between € 140 (USD $ 155) and € 150 (USD $ 166). Furthermore, all diving centers advertise dive packages, which may include accommodation, dive activities and, in some cases, international flights.

2.3. Tourist questionnaire

Dive tourist questionnaires were developed to document not only the diver's trip expenses but also their willingness to pay (WTP) for the enforcement and management of a MPA for sharks. Prior to data collection, a pilot survey of 30 dive tourists at different shark-diving centers was conducted for testing the questionnaire. The survey (Supplementary material) was divided into 3 sections: a) motivation for visiting the Azores Islands; b) the expenditure while in the Azores; and c) satisfaction with the shark-diving experience. Each section constituted of five-10 objective questions.

The first section of the questionnaire collected information about the following aspects: number of times visiting the Azores; main reason for visiting this region; and number of days spending on shark-diving activities. The expenditures while in the region included: total expenses (excluding international flights); and expenses per item (food and drinks, accommodation, local transport, souvenirs and gifts, diving, shark diving, tourist activities, international flights, domestic flights and other expenses). The last section of the questionnaire was focused on: average number of sharks sighted; satisfaction with the operation on a scale from 1 (poor) to 5 (excellent) in terms of: number of sharks sighted, quality of interaction with sharks and total satisfaction; likeliness to recommend or repeat the activity, and a specific question if they would have come to the region if there were not sharks to be sighted. In this section we also included two contingent valuation questions, in which divers were asked for their maximum WTP by an extra daily fee to provide resources for enforcement and management of a MPA for sharks in the Azores, as well as an extra daily fee for the enjoyment of the shark-diving activity if the cost of the operation increased. Furthermore, we included a question regarding suggestions of where the extra amount should be invested (e.g. diver security, shark conservation, etc.).

2.4. Operator questionnaire

Questionnaires for the dive operators aimed to obtain information about the characteristics of the business and expenditures of the diving operation. The data gathered included: a) number of tourists involved in general dive trips and shark-diving trips; b) main dive attractions and activities; c) shark-diving sites; d) frequency of shark encounters; e) operational costs; f) employment; g) expectations regarding the dive industry in the region and enforcement of a MPA for sharks.

2.5. Survey implementation

The on-site surveys were conducted between August and October 2019 with the four main Azorean diving centers providing shark-diving trips, which accounted for 85% of the total shark-diving industry, based in Faial and Pico Islands. The surveys targeted separately both shark-diving tourists and dive operators. These self-administrated questionnaires were designed based on the standardized methodology described by Vianna et al. (2011) and largely applied for shark-diving economic impact valuation studies (Vianna et al., 2011; Vianna et al., 2012; Haas et al., 2017; Huveneers et al., 2017, Vianna et al., 2018; Mustika et al., 2020), including the Azorean industry assessment in 2014 (Torres et al., 2017). Additionally, we also used the information gathered through personal inquiries to the main authors of these studies.

Questionnaires were distributed to dive tourists of the targeted dive centers in the ports of Horta (Faial Island) and Madalena (Pico Island). The tourist survey was performed under the supervision of the principal researcher with a brief introduction about the research. Most of the questionnaires were issued to the dive tourists once they returned from shark-diving trips.

Some other respondents were personally contacted on the following days of the operation at the dive centers or the surroundings as they still remained on the island.

2.6. Estimates of regional economic impact from shark-diving tourism

The regional economic contribution yielded by the shark-diving industry in the Azores was estimated based on combined data from all individual divers' expenditures and characteristics of the dive operators' business. These estimates capture the business revenues brought to the region by the shark-diving industry in terms of: a) the direct and indirect business revenues; b) business tax revenues; and c) the revenues to the local community in the form of salaries (Vianna et al. 2011). Direct business revenues included the revenues of shark-diving operators and indirect business revenues included accessories services such as hotels, restaurants, car rentals, tourism operators, regional airlines, and souvenir shops. Dive tourists were classified into two categories: (1) dedicated shark divers and (2) opportunistic shark divers. The first category included those divers who stated that they would not have visited the Azores if they could not dive with sharks. Thus, all associated travelling expenditures for these divers, and calculation of associated benefits, can be attributed directly to shark-diving tourism. Opportunistic shark divers included those divers who would have visit the Azores regardless of the possibility to dive with sharks. Expenditures were calculated for opportunistic shark divers based on the average number of days diving with sharks and for dedicated shark divers based on the average number of days staying in the Azores. To further reduce the influence of leakage between sectors of the economy, the analysis of total revenues from shark diving did not include international flights. The total number of shark-diving tourists in the Azores Islands in 2019 was provided by the combined set of dive operators. The average expenditure of divers was calculated based on the data collected in the tourist survey. The average daily expenditure of dedicated and opportunistic shark divers was assumed as the same. The economic variables and formulas for data analyses are shown in Table 1 and Supplementary data.

We recognized that our estimates of business revenues are a supply side approximation of tourist expenditure and do not equate to the total economic benefits from the shark-diving industry since shark-diving services contribute to a wider range of market and non-market values (Just et al., 2004). However, the revenue approximation provides a useful indicator of the economic importance of the industry and is consistent with common economic metrics such as Gross Domestic Product and National Income Accounting (Vianna et al., 2012).

2.7. Willingness to pay

We estimated the willingness to pay (WTP) of dive tourists for an extra daily fee used for management and enforcement of a hypothetical MPA for sharks (Vianna et al., 2018) and for the enjoyment of the shark-diving activity if the cost of the operation increased. The contingent valuation questions were framed by using a payment card, that showed tourists five categories of user fees per trip in Euros (€) of 0, <30 (USD $33), 30-60 (USD $ 33-67), 61-90 (USD $ 68-100), >90 (USD $ 100). The bids were chosen based on local knowledge of dive operators about user fees from international marine reserves. Respondents were asked to select their maximum WTP from the offered bid amounts. The payment card approach allowed us to observe the lower and upper bound of respondent's WTP, with unbounded intervals for the extreme responses on the card, while also considering individuals with zero WTP values.

That is, from a modelling perspective, the individual is asked to choose between a set of intervals that comprising his/her willingness to pay, leading to monetary values within

censored intervals. The bounds of the interval chosen would determine the largest and the minimum amount of money that the subject would be willing to pay for management and enforcement of a proposed MPA for sharks and the enjoyment of the shark-diving activity if the cost of the operation increased. For individual *i*, let L_i and U_i be the lower and the upper bounds of the chosen interval, respectively. $L_i = -\infty$ for those individuals choosing the lowest interval on the payment card, while for those choosing the highest interval on the payment card, $U_i = +\infty$. There can also be some individuals for whom WTP is not censored, since they state that they would not pay any amount of money, i.e. WTP is zero.

Thus, in this paper we propose the estimation of a spiked censored interval regression model, similarly to Kriström (1997) for the single bounded dichotomous choice approach. This model allows for the consideration of individuals who answer a zero WTP value together with other individuals who choose some of the intervals in the payment card.

Therefore, the probability that the monetary value for individual *i* is located in the interval is

$$\Pr(L_i \le WTP_i \le U_i) = \int_{L_i}^{U_i} f(WTP_i)\, dWTP_i = F(U_i) - F(L_i) \quad (1)$$

where WTP_i is willingness to pay for individual *i*, *F* is the cumulative distribution function of willingness to pay, and *f* is the probability density function, with $F(-\infty) = 1$ and $F(+\infty) = 0$. The log likelihood function is derived by aggregation through the sample. That is,

$$\ell = \sum_{i=1}^{i=n} \log(1 - I_i)\left[F(U_i) - F(L_i)\right] + \log I_i \left[f(0)\right] \quad (2)$$

where I_i is an indicator function that takes the value of 1 if the individual states a zero WTP, and 0 if the respondent chooses some of the intervals on the payment card. The parameters that maximize the log-likelihood function can be obtained by iterative methods such as Newton-Raphson or simulation methods. WTP_i can be a function of explanatory variables, such as $WTP = \beta X_i + \varepsilon_i$, where X_i is a vector of characteristics of the individual, β is a vector of parameters, and ε_i is an error term which is normally distributed.

Table 1: Description of constants and parameters used to estimate revenues generated by the shark-diving industry in the Azores Islands.

Variable		Description (units)	Values	Source
D	# divers	Total number of dive tourists in the Azorean diving centers advertising shark-diving trips (#/yr)	20,140	Dive operator questionnaire
SD	# shark divers per year	Total number of dive tourists engaged in shark-diving operations in the Azores (#/yr)	1,007	Dive operator questionnaire
DSD	# dedicated shark divers per year	Estimated number of dedicated shark divers visiting the Azores per year (#/yr)	306	Dive operator questionnaire
SDF	Shark divers' fraction	Proportion of dive tourists engaged in shark-diving operations (SD/D)	0.05	Dive operator questionnaire
DSDF	Dedicated shark divers' fraction	Proportion of dedicated shark divers (DSD/SD)	0.3	Tourist questionnaire
W	Wages	Average salary of employees of shark-diving industry in the Azores (€/yr)	8,740	Dive operator questionnaire
BT	Business tax contribution	Minimum tax rate contribution from shark-diving businesses	0.04	Dive operator questionnaire
E	Number of employees	Estimated number of local employees in the shark-dive industry in the Azores	53	Dive operator questionnaire
A	Average days of diving	Average number of days diving with sharks in the Azores (days)	2.7	Tourist questionnaire
T	Average days of trip	Average number of days staying in the Azores	11.5	Tourist questionnaire

3. Results

3.1. Data collected and respondent profile

We collected 118 questionnaires, of which 115 were answered by dive tourists and 4 by dive operators (representing 85% of the Azorean shark-diving industry). Dive tourists were between 25-60 years old and came from eight countries: USA, Canada, Germany, Russia, Italy, Spain, France and Portugal. For most of respondents (~68%), this was the first trip to the Azores; however, about 21% had been in the region before. General diving activities was indicated as the main reason to visit the Azores (~37%), followed by general tourism (~22%). Approximately 15% of the respondents stated they traveled to the Azores specifically to dive with sharks. The average total length of the trip for all divers was 11.5 days, and 2.7 days for specifically diving with sharks (Table 2).

Approximately 30% of shark-diving tourists were classified as dedicated shark divers since they stated that would have not come to the Azores if it was not possible to dive with sharks. This figure included the respondents who stated having travelled to the archipelago specifically to dive with sharks, but also included divers who prioritized this destination because of shark diving (as a decision factor) but also to diversify their holidays with activities other than shark diving. Regarding shark-diving activities, the average number of sharks seen per dive was 2.6, and 77% of tourists would definitely repeat this activity or recommend it to other people. Overall, the shark-diving trip was qualified as "excellent" by the majority of the tourist divers (69%) and as "good" for 24% (Fig. 2). Regarding the willingness to pay survey, 47% of respondents would pay less than € 30 (USD $ 33) as an extra fee per dive trip with the aim of enforcing a proposed MPA for sharks in the Azores (Fig. 3). If the cost of shark dive operation increased, over 40% of tourists would pay an extra fee higher than € 30. Most of respondents (~71%) reported they would like to see this extra revenue invested into shark conservation (Fig. 4).

Table 2: Summary of divers' answers.

Divers' profile	Value
Average trip days (mean # of days ± SD)	11.5 (± 4)
Average days of shark diving (mean # of days ± SD)	2.7 (± 3)
Shark diving was the main purpose of the trip (%)	14.8
Dedicated shark diver fraction (%)	30.4
Average number of sharks watched (mean # of days ± SD)	2.6 (± 1.3)
§ Likeliness to repeat or recommend the shark-diving experience (%)	
Definitely	77.4
Likely	16.5
Maybe	4.4
Unlikely	0
No	0

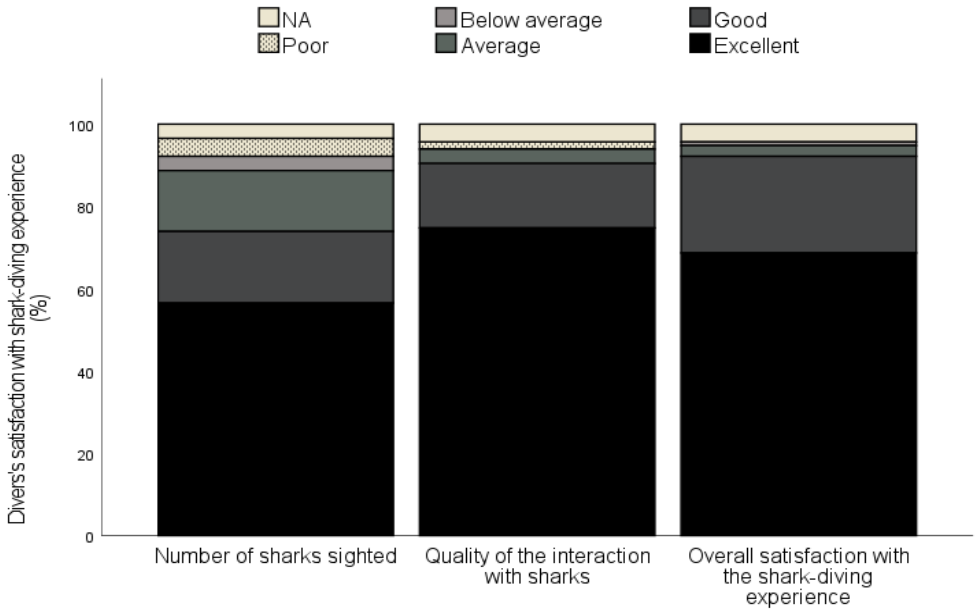

Fig. 2. Divers' satisfaction with shark-diving experience in terms of number of sharks sighted, quality of the interaction with sharks and overall satisfaction.

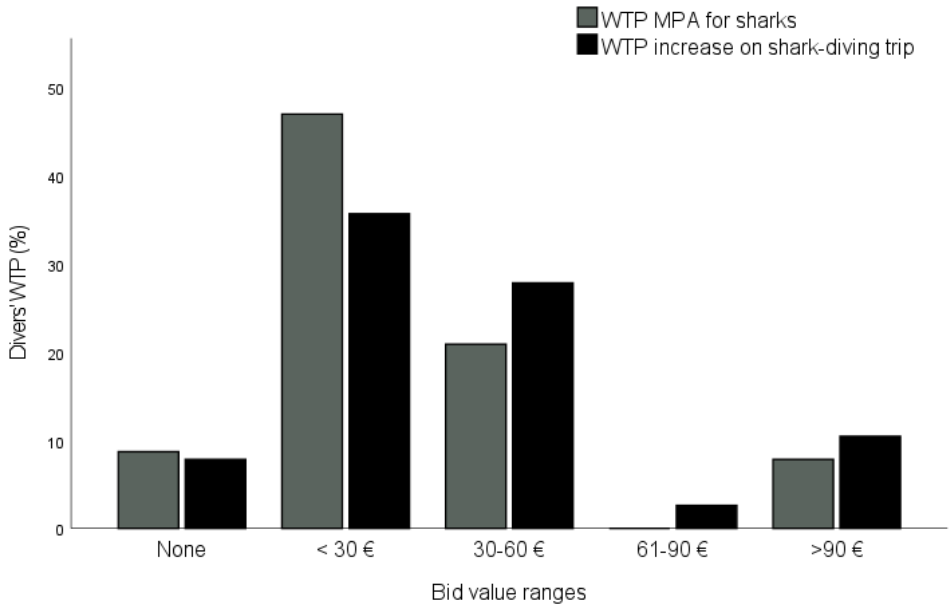

Fig.3. Divers' willingness to pay (WTP) for management and enforcement of a MPA for sharks and for shark-diving trip if its cost increased.

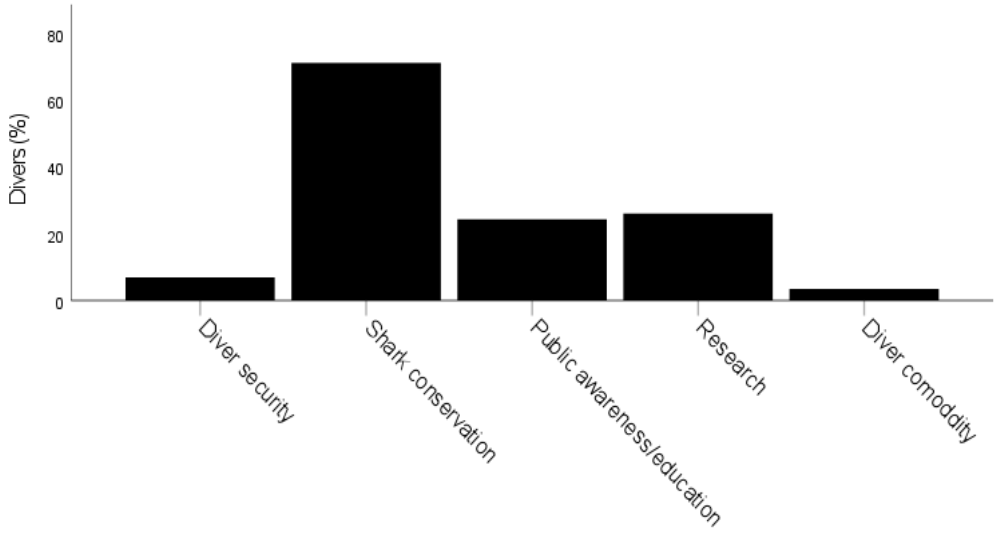

Fig.4. Divers' choice of area of investment of extra-amount per dive trip

3.2. Economic impact of shark-diving industry

Our study revealed that the total economic impact generated by shark-diving tourists in the regional economy of the Azores in 2019 was € 932,603 (USD $ 1,035,189), of which approximately 65% was attributed to dedicated shark divers. The expenditure of the dedicated shark divers that would not have visited the Azores if shark-diving activities were not advertised would have been lost to the region and therefore is entirely attributable to the main attractions, blue and shortfin mako sharks. Economic benefits from shark-diving reached the community in the form of salaries to local employees of the shark-diving industry. A total of 53 local employees were working directly for the Azorean diving centers providing shark-diving operations. Given that the total number of shark-diving tourists per year represents 5% of the total annual number of all divers in the Azores, this activity generates € 23,161 (USD $ 25,709) to the local community. Considering the minimum tax rate contribution of 4%, the total business tax revenues from shark-diving tourism in 2019 was € 37,304 (USD $ 41,408).

Table 3: Estimated revenues and income generated by the shark-diving industry in the Azores Islands in 2019.

Code	Description	Value (€)	Value ($)
Annual business revenues			
BROSD	Business revenues from opportunist shark divers	340,245	377,672
BRDSD	Business revenues from dedicated shark divers	592,358	657,517
Total	Shark-divers	932,603	1,035,189
Annual community income			
DCID	Direct community income from diving	463,220	514,174
DCISD	Direct community income from shark-diving	23,161	25,709
Annual tax revenues			
BRTOSD	Business revenue tax from opportunist shark divers	13,610	15,108
BRTDSD	Business revenue tax from dedicated shark divers	23,694	26,300
Total	Business revenue tax from shark-divers	37,304	41,408

3.3. Willingness to pay

The willingness to pay (WTP) responses for the management and enforcement of an MPA for sharks and for the enjoyment of the shark-diving activity if the cost of the operation increased are modeled utilizing a censored regression approach that allows for the consideration of zero values and unbounded intervals. The variables that were significant explaining WTP values are described in Table 4, while Table 5 presents the model results.

It can be seen that WTP for a proposed MPA for sharks is higher for those dive tourists that have experienced an excellent quality with the shark-diving activity, have spent more on their vacation in the Azores, have been before in the islands, come to the islands for shark diving as a main reason and would like to strongly recommend the visit to Azores to other people. The mean WTP for the censored regression model is € 34.7 with a 95% confidence interval ranging from € 10.8 to € 51.7. For the enjoyment of the shark-diving activity if the cost of operation increased, WTP is significantly higher for those tourists who have perceived a higher quality of the experience, have spent more on their vacation and have been before in the islands. The mean of the maximum extra fee, or WTP, for the diving activity is € 38.93, with a confidence interval from € 15.6 to € 62.2.

The average individual WTP estimates were aggregated over the total number of shark-divers per year (*SDT*) and the average number of diving days (*A*) to obtain the potential annual revenues from an extra fee per shark-dive trip (*REV*) (Supplementary material). Based on the mean WTP for management and enforcement of a hypothetical MPA for sharks from respondents, the proposed MPA could generate an estimated annual revenue (REV) of € 94,346 (USD $ 103,780) (confidence interval: € 29,364–14,0567) (USD $ 32,301–154,624) from extra fee per shark-diving trip. Based on the mean WTP for the enjoyment of the shark-diving activity if the cost of operation increased, this situation could generate an estimated annual revenue of € 105,847 (USD $ 116,431) (confidence interval: € 42,415–169,116 (USD $ 46,656– 186,027) from extra fee per shark-diving trip.

Table 4: Variables in the WTP model.

Variable	Description
Quality	Dummy variable that takes the value of 1 if the subject rates the quality of the tourist experience with sharks as excellent, 0 otherwise.
Expenditure	Total expenditure in the visit to Azores in Euros over 1000.
Main	Dummy variable that takes the value of 1 if the subjects' main reason for visiting the Azores was to dive with sharks, 0 otherwise.
Before	Dummy variable that takes the value of 1 if the subject had been in Azores before, 0 otherwise.
Recommend	Dummy variable that takes the value of 1 if the subject definitely recommends the visit to Azores to other people, 0 otherwise.

Table 5: Censored interval regression results of divers' WTP for management and enforcement of a hypothetical Marine Protected Area (MPA) for sharks and for shark-diving trip if the cost of the operation increased.

	MPA for sharks			Increase on shark-diving trip		
Variable	Coefficient	Std. err.		Coefficient	Std. err.	
Constant	6.46	3.94	*	15.11	7.62	*
Quality	19.61	7.88	***	25.24	12.08	**
Expenditure	5.022	2.36	**	3.014	1.66	*
Main	7.88	3.17	**	9.23	6.17	
Before	13.87	3.87	***	12.63	7.69	*
Recommend	5.77	2.14	***	12.51	8.81	
ln (s)	2.67	0.12	***	3.51	0.10	***
N	97			97		
Log-likelihood	-102.24			-167.003		
McFadden's R2	0.411			0.181		
McFadden's Adj R2	0.370			0.102		
AIC	218.495			348.006		
BIC	-118.794			-178.44		
LR(5)	142.519			99.10		
Mean WTP (€)	34.7	10.8 – 51.7		38.93	15.6 – 66.2	

Notes: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.001$

The cumulative distribution of WTP responses for a proposed MPA for sharks shows that nearly 30% of respondents were willing to pay more than € 30 and approximately 10% of respondents were not willing to pay an extra fee to enforce the proposed MPA for sharks (Fig. 5).

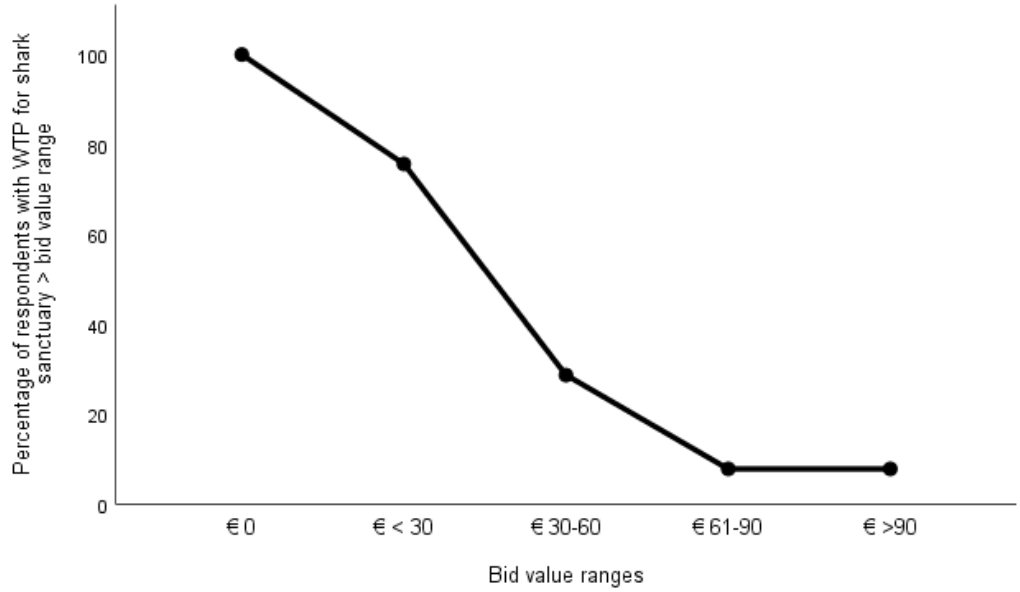

Fig. 5. Cumulative distribution of WTP for a proposed MPA for sharks responses showing the percentage of respondents who were willing to pay the amount specified by each bid range category.

4. Discussions

4.1. Economic impact of the shark-diving industry in the Azores Islands

The total economic contribution generated by the shark-diving industry in the Azores was estimated as USD $ 1,035,189, which is significantly lower compared to other small-island industries in the world such as Fiji (USD $ 42 million), Palau (USD $ 18 million), French Polynesia (USD $ 5.4 million) or Fernando de Noronha in Brazil (USD $ 2.6 million) (Table 6, Clua et al., 2011; Vianna et al., 2011; Vianna et al., 2012; Pires et al., 2016). This could be mainly explained by the number of divers (1,007) and the observed short shark-diving season, but most critically that the Azorean shark-diving industry has recently emerged (started in 2011), and that tourism is still burgeoning in the archipelago (Azorean Statistical Office, 2017; Vieira et al., 2019). Unlike the other small-island destinations, the main shark-diving attractions in the Azores are oceanic shark species (blue shark and shortfin mako shark), which appear seasonally in the regional waters, therefore, shark-diving activities are only operated for three months per year, during the summer period, similar to what was reported by Gallagher & Hammerschlag (2011) in places such as Rhode Island (USA) and Southern California (USA). However, if we standardized by number of years and operations, the Azorean shark-diving tourism would be among the highest and most profitable small-island industries considering its reliance in the European economy which is stronger than in the other diving destinations (Table 6).

Table 6: Comparing the commercial value of shark-diving industries in island destinations

Shark-diving destination	Year	Number of divers	Season length	Average expenditure per trip (USD)	Average expenditure per day (USD)	Total business revenues (USD million)
Fiji	2011	49,000	Year-round	2,300	212	42.2
Palau	2010	8,600	Year-round	-	-	17.4
French Polynesia	2009	12,623	Year-round	-	325	5.4
Fernando de Noronha	2014	4,400	Year-round	1,483	269	2.6
The Azores	2014	1,280	3 months	3,672	322	2.2
The Azores	2019	1,007	3 months	2,189	203	1.0

In 2014, Torres et al. (2017) estimated the revenues generated by the Azorean shark-diving industry in over USD $ 2 million per year (Table 4); the study included estimates of direct, indirect and induced revenues from shark-diving. As observed in our results, the total number of shark-diving tourists in 2019 has decreased compared to 2014 (273 fewer tourists), and this difference represents over 27% of the total number of dive tourists in 2019 (1,007 shark-diving tourists). This could partially explain why the total business revenues in 2014 were higher than our estimation in 2019; however, the difference between the two studies is still substantial after accounting for the smaller number of tourist in 2019, which is likely a consequence of the inclusion of international flights in dive tourist expenditures estimated by Torres et al. (2017). In our study we did not include this category of expenditure in order to focus on the revenues that are retained in the Azorean economy, as opposed to revenues that may leak to foreigner countries. Another factor that could potentially explain the difference between these estimates is the proportion of dedicated shark divers. In Torres et al. (2017), dedicated shark divers represented nearly the half of the total number of tourists engaged in shark-diving activities (44%), while in 2019 our study found this to be 30%. This difference reduced the total revenue estimate in our study, as the expenditures of dedicated shark divers were calculated based on the average number of days staying in the Azores and not only for the average number of days diving with sharks (i.e. opportunist shark divers). This large difference in the number of tourists engaged in shark-diving activities may be related to differences in the survey sampling design. The survey performed by Torres et al. (2017) mostly targeted divers utilizing one of the four major diving centers, while our survey targeted the entire shark-diving industry and was successful in sampling 85 % of the dive operators. According to the dive operators, the diving center targeted by Torres et al. (2017) historically hosts most of the shark-diving tourists in the region, which was also confirmed in our results (about 30% of the entire industry). We observed that the average expenditure of divers utilizing this diving center was 30% higher than those of dive tourists in the other diving centers (€ 163.7 per day), which could also partially explain the higher values estimated by Torres et al. (2017).

This comparison unequivocally demonstrates the need for analyses of shark-diving socioeconomics to be representative of the entire industry in order to obtain a more accurate estimate of the total economic impact in the region. As more standardized valuation studies become available, these data may assist the development of models that could predict the potential of diving tourism to finance the implementation of management and conservation strategies (Vianna et al., 2018).

Despite the smaller size when compared to shark-diving industries in many other countries, this industry in the Azores has the potential to grow due to the optimal conditions for diving practices (Ressurreição & Giacomello, 2013), high probability of shark sightseeing (i.e. blue sharks) and the current expansion of the nature-based tourism industry in the Azores (Vieira et al., 2019). According to the dive operators, other potential shark-diving sites can be found in the archipelago such as Azores and Joao de Castro Banks and this could lead to a higher number of diving centers engaged with shark-diving activities. Additionally, the average expenditure per day for diving with sharks in the Azores is lower compared to the other mentioned shark-diving destinations (i.e. Fiji, French Polynesia and Fernando de Noronha), which could encourage dedicated shark divers, particularly from Europe, to visit/return to the Azorean archipelago for this reason.

4.2. Local community income from shark-diving industry in the Azores Islands

The direct local community income generated by the Azorean shark-diving industry was also lower than other small-island industries; however, expenditure on shark-diving had flow-on effects for the local economy, benefitting businesses that might not be directly involved in the industry such as accommodation, transport, restaurants, etc. (Vianna et al., 2018). Also, considering that diving activities occur in the Azores for 5 months per year, local workers in diving centers receive a higher income per month during this period than the average monthly income in other sector of the economies (Azorean Statistical Office, 2019). Still, the annual average salary of the local community engaged in the diving industry may appear relatively small due to the short diving season. This suggests that the growth in the number of shark-diving operations and the development of a coastal shark diving year-round could further expand the Azorean shark-diving industry and increase community income.

Considering the potential interaction of fisheries and shark-diving tourism in the Azores, it is important to discuss the revenues produced by shark landings in the Azorean Economic Exclusive Zone (EEZ). Pelagic longlines land the largest majority of shark catches in this region (Das & Afonso, 2017), with blue and shortfin mako sharks accounting for most of the catches (Queiroz et al., 2019; Santos et al., 2020). According to Torres et al. (2016), the total landed value of these pelagic species in 2014 was less than € 20,000 (USD $ 22,000) in the Azorean market, which evidenced lower benefits of catches of blue shark and shortfin mako shark for the local fishers compared to other more valuable fish species (e.g. swordfish, tuna, etc.). The low local demand for pelagic sharks in the regional market has led to a high discarding of blue and shortfin mako sharks in domestic fleets (Pham et al., 2013; Fauconnet et al., 2019). Yet, local pelagic longlines in the Azores operate at a much smaller scale compared to European industrial pelagic fleets (Correa et al., 2016). In contrast, the majority of shark catches from mainland and foreign fleets are landed in mainland European harbours, where shark meat and fins have a higher market value and management restrictions (quota or MLS) for these species are absent (Fauconnet et al., 2019). This suggests that there is a large underestimation of the pelagic shark catches in the Azorean waters and the value of this industry.

As pelagic shark catches have a minor socio-economic impact in the Azorean local community (Carvalho et al., 2011; Pham et al., 2013), the non-consumptive use of sharks through the shark-diving tourism industry may potentially represent a higher source of income and provide more job opportunities. Local fishers could also benefit from the increasing presence of shark-diving tourists through a higher demand for more sustainable fish products regionally, which could make local fishers encouraged to reduce bycatch and particularly discards of blue and shortfin mako sharks, and to support the shark-diving tourism industry (Vianna et al., 2012).

4.3. The shark-diving experience in the Azores Islands

The overall shark-diving experience in the Azores was highly valued by dive tourists (rated "Good" or "Excellent" by 92% of respondents), which may explain why 77% of the divers interviewed would definitely return or recommend this activity. Our results in the assessment of the overall shark-diving experience and the average number of shark sightings per trip (2.6 sharks) had similar results to the survey performed in 2014. However, in our survey we included a specific question about the number of shark sightings per trip and 23% of respondents expressed a relatively low degree of satisfaction. This may reflect the dive tourist preference for consistent shark sightings and that observing fewer individuals of blue and shortfin mako shark in the future could negatively affect the motivation to perform this activity. According to the dive operators, shortfin mako sightings have largely diminished in the shark-diving operations in recent years, which is likely a consequence of increasing fishing pressure and overfishing (Worm et al., 2013; Campana, 2016; Torres et al., 2016). As stated by Zimmerhackel et al. (2018), evidence of shark population declines in shark-diving destinations may trigger a substantial decrease in demand for dive trips with economic losses not only to the dive industry, but also to the broader local tourism market. Conversely, increasing abundance of sharks may further increase demand and generate higher economic gains (Zimmerhackel et al., 2018), which could be potentially achievable with the enforcement of MPAs for sharks.

4.4. Willingness to pay (WTP) for a proposed MPA for sharks in the Azores Islands

Willingness-to-pay studies have been widely used to investigate the acceptance and optimal value of hypothetical marine park fees, including MPAs for sharks, and inform decision makers of the financing potential of fee implementation (McDonald et al., 2016; Haas et al., 2017; Vianna et al., 2018, Schuhmann et al., 2019). Our results show that the shark diving-industry in 2019 could generate over € 94,300 (USD $ 103,700) for the management and enforcement of a proposed MPA for sharks. This represents an increase in the willingness to pay by divers utilizing this industry when compared to a similar survey from 2014 (Torres et al., 2017), which estimated that a total amount of € 62,720 (USD $ 68,992) could be generated for the same matter. This difference could be associated to a general trend of increasing of concern by divers with the protection of shark populations. However, it was also observed that if the cost of shark-diving operations would increase, tourist divers could pay a higher extra fee generating € 105,847 (USD $ 116,431), and for most of them (71 %) this amount should be invested in shark conservation. This could be explained by the fact that tourist divers perceive that the Azorean government may be falling short to protect shark populations, as stated by some respondents, and would prefer to support independent shark conservation initiatives such as promoted by diving centers.

Our WTP model analysis shows that dive tourists who had a higher quality of experience, a higher average expenditure in the Azores and have returned to the region would be willing to pay more for the enforcement and management of an MPA for sharks and in case the cost of the shark-dive trip increased. It seems logical that dive tourists who have returned to the Azores and were highly satisfied with the shark-diving trip would like to repeat the experience with shark populations and their habitat well-conserved, even if the cost of the operation increased. It also seems logical that dive tourists who spent more in the region would be able to pay more for the activity and to financially assist shark conservation actions. We also observed that over 90% of the dive tourists were willing to contribute financially to the establishment of a MPA for sharks which could be related to the general high satisfaction with

the activity. However, the implementation of any fee payment scheme must consider potential effects on return rates of individual tourists through further market research or contingent behaviour studies (Vianna et al., 2018).

The Azores is a pioneer in the region in the implementation of a set of marine conservation instruments through MPAs, having started in the 1980's when few countries were actively engaged in marine spatial management for conservation (Abecasis et al., 2015). With 110,000 km^2 of extension, the current established network of the Azorean MPAs has achieved a representative coverage of a full range of ecosystems habitats and vulnerable marine environments, along with the establishment of large offshore MPAs both within and beyond the Azorean EEZ (O'Leary et al., 2012). However, Azorean MPAs cannot fully protect the populations of a large number of migratory species that visit the archipelago such as oceanic shark species because only part of their life cycle is spent within Azorean waters (Abecasis et al., 2015). Moreover, underfunding for monitoring, enforcement, management, and public and stakeholder engagement is also challenging in the region, as in most MPAs worldwide (Edgar et al., 2014; Worm, 2017). Despite some MPAs around shark-diving sites in the Azores have been implemented banning certain fishing activities (e.g. demersal fisheries in Condor Bank), these reserves still lack effective protection (Afonso et al., 2018).

Shark-diving tourism has demonstrated to be a financial mechanism for protection of sharks and their habitats through conservation strategies and management in many diving destinations around the world (Brunnschweiler, 2010; Vianna et al., 2012; Vianna et al., 2018). However, this engagement relies on how significant the economic contribution of the shark-diving industry for the regional economy is (Gallagher et al., 2015). The total business revenues generated by the Azorean industry may not currently represent a strong contributor of economic outcomes for the local community and to support strong conservation strategies. However, prohibitions on shark fisheries through the implementation of MPAs for sharks would not be challenging for local fishers and the overall local community. The marine environment is deeply rooted in Azorean livelihoods and culture, and recent studies show that most Azorean people consider marine conservation a priority and are willing to engage to avoid loss of marine biodiversity (Ressurreição et al., 2011, 2012). The main stakeholder affected by a shark fisheries ban would be the European industrial fleets, which are the largest pelagic shark fisheries in the Azorean waters, and that potentially threaten the expansion of the shark-diving industry. Conversely, the establishment and adequate management of MPAs for sharks would only benefit the local economy and investing in shark conservation can increase this potential.

Finally, considering that enforcement of an MPA for protecting pelagic sharks is challenging due to their migratory patterns, this MPA would require a large-scale conservation planning with regional connectivity. Blue sharks and shortfin mako sharks move through the entire biogeographical region of Macaronesia, which also include the archipelagos of Madeira, Canary Islands and Cape Verde. This area is also a hotspot of large-distant industrial fisheries targeting pelagic sharks (Queiroz et al., 2019) with signs of significant overfishing (Link et al., 2020). In light of these facts, supra-regional control measures could be implemented to reduce shark-fishing mortality through the implementation of a network of pelagic MPAs in Macaronesia. This region has also shown a high potential for the development of shark-diving tourism (Gonzáles-Mantilla et al., 2020), which could potentially generate funds to assist the enforcement and adequate management of these marine reserves. Hence, good practices in the Azorean shark-diving industry would not only serve as an example for the other Macaronesian archipelagos, but for other small-islands sharing similarities in terms of overlapping of pelagic industrial fisheries and oceanic shark populations.

5. Conclusions

Our study investigated the economic value of the shark-diving tourism industry targeting pelagic or oceanic sharks in the Azores Islands and the potential of generation revenues for conservation. Despite being one of the most widespread group of sharks in the world, the species focused on here (blue and shortfin mako) have been modestly represented among global shark-diving tourism operations (over 10%, Gallagher & Hammerschlag, 2011), and our findings contribute to a better understanding of the potential economic dimensions of this emergent market in the Mid-Atlantic. The contingent valuation analysis based on the willingness to pay survey shows that the Azorean shark-diving tourism could assist financial resourcing for the implementation of a MPA for sharks. However, this industry needs to expand in order to represent a strong contributor of economic outcomes for the local community and to support strong conservation strategies.

The growth possibilities of the Azorean shark-diving industry depend mainly on attracting a greater number of tourists to the region, particularly dedicated shark divers. A wider awareness among local authorities about the economic benefits of this potentially sustainable industry is needed, with the aim to improve marketing strategies, increasing support for local dive centers to explore this market, and to integrate more local workers from the Azorean community into the shark-diving industry.

References

Afonso, P., Schmiing, M., Fontes, J., Tempera, F., Morato, T., & Santos, R. S. (2018). Effects of marine protected areas on coastal fishes across the Azores archipelago, mid-North Atlantic. Journal of Sea Research, 138, 34-47.

Arrow, K., Solow, R., Portney, P. R., Leamer, E. E., Radner, R., & Schuman, H. (1993). Report of the NOAA panel on contingent valuation. Federal register, 58(10), 4601-4614.

Arthur, L. (2011). A case study of divers' willingness to pay tourist fees towards shark conservation in The Maldives. Masters, University of Newcastle, Newcastle.

Aseres, S. A., & Sira, R. K. (2020). Estimating visitors' willingness to pay for a conservation fund: sustainable financing approach in protected areas in Ethiopia. Heliyon, 6(8), e04500.)

Azorean Statistical Office (2017). Séries Longas – Turismo. Angra do Heroísmo, SREA.

Azorean Statistical Office (2019). Statistical Yearbook of the Azorean Region 2018.

Bentz, J., Dearden, P., Ritter, E., & Calado, H. (2014). Shark-diving in the Azores: challenge and opportunity. Tourism in Marine Environments, 10(1-2), 71-83.

Brunnschweiler, J. M. (2010). The Shark Reef Marine Reserve: a marine tourism project in Fiji involving local communities. Journal of Sustainable Tourism, 18(1), 29-42.

Boyle, K. (2003). Contingent valuation in practice. In 'A Primer on Non-Market Valuation'. (Eds P Champ, K Boyle, T Brown) pp. 111–170.

Calado, H., Ng, K., Lopes, C., & Paramio, L. (2011). Introducing a legal management instrument for offshore marine protected areas in the Azores—The Azores Marine Park. Environmental science & policy, 14(8), 1175-1187.

Campana, S. E. (2016). Transboundary movements, unmonitored fishing mortality, and ineffective international fisheries management pose risks for pelagic sharks in the Northwest Atlantic. Canadian Journal of Fisheries and Aquatic Sciences, 73(10), 1599-1607.

Carson, R. T. (2000). Contingent valuation: a user's guide.

Carvalho, N., Edwards-Jones, G., and Isidro, E. (2011). Defining scale in fisheries: small versus large-scale fishing operations in the Azores. Fish. Res. 109, 360–369. doi: 10.1016/j.fishres.2011.03.006

Casey, J. F., Brown, C., & Schuhmann, P. (2010). Are tourists willing to pay additional fees to protect corals in Mexico?. Journal of Sustainable Tourism, 18(4), 557-573.

Catlin, J., Hughes, M., Jones, T., Jones, R., & Campbell, R. (2013). Valuing individual animals through tourism: Science or speculation?. Biological conservation, 157, 93-98.

Cazabon-Mannette, M., Schuhmann, P. W., Hailey, A., & Horrocks, J. (2017). Estimates of the non-market value of sea turtles in Tobago using stated preference techniques. Journal of environmental management, 192, 281-291.

Clua, E., Buray, N., Legendre, P., Mourier, J., & Planes, S. (2011). Business partner or simple catch? The economic value of the sicklefin lemon shark in French Polynesia. Marine and Freshwater Research, 62(6), 764-770.Correia, J. P., Morgado, F., Erzini, K., and Soares, A. M. V. M. (2016). Elasmobranch landings in the portuguese commercial fishery from 1986 to 2009. Arquipel. Life Mar. Sci. 33, 81–109. Available online at: http://hdl.handle.net/10400.3/3983

Couto, G., Pimentel, P., & Ponte, J. C. B. D. (2017). Tourism development potential in an insular territory: the case of Ribeira Grande in the Azores. CEEAplA-A-Working Paper Series, 1-23.

Das, D., & Afonso, P. (2017). Review of the diversity, ecology, and conservation of elasmobranchs in the Azores region, mid-north Atlantic. Frontiers in Marine Science, 4, 354.

Davidson, L. N., & Dulvy, N. K. (2017). Global marine protected areas to prevent extinctions. Nature ecology & evolution, 1(2), 1-6.

Dentinho, T. P., & Fortuna, M. A. (2019). How Regional Governance Constrains Regional Development. Evidences From an Econometric Base Model For the Azores. Revista portuguesa de estudos regionais, (52), 25-35.

Edgar, G. J., Stuart-Smith, R. D., Willis, T. J., Kininmonth, S., Baker, S. C., Banks, S., ... & Buxton, C. D. (2014). Global conservation outcomes depend on marine protected areas with five key features. Nature, 506(7487), 216-220.

Fauconnet, L., Pham, C. K., Canha, A., Afonso, P., Diogo, H., Machete, M., Silva, H. M., Vandeperre, F., & Morato, T. (2019). An overview of fisheries discards in the Azores. Fisheries Research. 209:230–241. doi:10.1016/j.fishres.2018.10.001.

Frontuto, V., Dalmazzone, S., Vallino, E., & Giaccaria, S. (2017). Earmarking conservation: Further inquiry on scope effects in stated preference methods applied to nature-based tourism. Tourism Management, 60, 130-139.

Gallagher, A. J., & Hammerschlag, N. (2011). Global shark currency: the distribution, frequency, and economic value of shark ecotourism. Current Issues in Tourism, 14(8), 797-812.

Gallagher, A. J., Vianna, G. M., Papastamatiou, Y. P., Macdonald, C., Guttridge, T. L., & Hammerschlag, N. (2015). Biological effects, conservation potential, and research priorities of shark-diving tourism. Biological Conservation, 184, 365-379.

Gallagher, A.J. and Huveneers, C. P. (2018). Emerging challenges to shark-diving tourism. Marine Policy, 96, pp.9-12.

Gallagher, A. J., Amon, D., Bervoets, T., Shipley, O. N., Hammerschlag, N., & Sims, D. W. (2020). The Caribbean needs big marine protected areas.

Gonzáles-Mantilla, P. G., Gallagher, A. J., León, C. J., & Vianna, G. M. (2021). Challenges and conservation potential of shark-diving tourism in the Macaronesian archipelagos. Marine Policy, 131, 104632.

Haas, A. R., Fedler, T., & Brooks, E. J. (2017). The contemporary economic value of elasmobranchs in The Bahamas: Reaping the rewards of 25 years of stewardship and conservation. Biological conservation, 207, 55-63.

Hanley, N., Barbier, E. B., & Barbier, E. (2009). Pricing nature: cost-benefit analysis and environmental policy. Edward Elgar Publishing.

Higginbottom, K. (Ed.). (2004). Wildlife tourism: Impacts, management and planning. Common Ground Publishing.

Hoyos, D., & Mariel, P. (2010). Contingent valuation: Past, present and future. Prague economic papers, 4(2010), 329-343.

Hoyt, E. (2014). The role of marine protected areas and sanctuaries, in: E.J. Techera, N. Klein (Eds.), Sharks: Conservation, Governance and Management, Routledge, pp. 236–261.

Huveneers, C., Meekan, M. G., Apps, K., Ferreira, L. C., Pannell, D., & Vianna, G. M. (2017). The economic value of shark-diving tourism in Australia. Reviews in Fish Biology and Fisheries, 27(3), 665-680.

Indab, A. L. (2016). Willingness to pay for whale shark conservation in Sorsogon, Philippines. In Marine and Coastal Ecosystem Valuation, Institutions, and Policy in Southeast Asia (pp. 93-128). Springer, Singapore.

Just, R. E., Hueth, D. L., & Schmitz, A. (2005). The welfare economics of public policy: a practical approach to project and policy evaluation. Edward Elgar Publishing.

Kaim, M. (2018). Green Entrepreneurship Management in Portugal: the case of Azores Islands. In Competitivitatea şi Inovarea în Economia Cunoaşterii (Vol. 2, pp. 368-372).

Kriström, B. (1997). Spike models in contingent valuation. American journal of agricultural economics, 79(3), 1013-1023.

Lewis, S. E. F., Turpie, J. K., & Ryan, P. G. (2012). Are African penguins worth saving? The ecotourism value of the Boulders Beach colony. African Journal of Marine Science, 34(4), 497-504.

Loomis, J. B., & Larson, D. M. (1994). Total economic values of increasing gray whale populations: results from a contingent valuation survey of visitors and households. Marine Resource Economics, 9(3), 275-286.

McDonald, G., Mangin, T., Thomas, L. R., & Costello, C. (2016). Designing and financing optimal enforcement for small-scale fisheries and dive tourism industries, Mar. Policy 67. 105–117.

Mieras, P. A., Harvey-Clark, C., Bear, M., Hodgin, G., & Hodgin, B. (2017). The economy of shark conservation in the Northeast Pacific: the role of ecotourism and citizen science. In Advances in marine biology (Vol. 78, pp. 121-153). Academic Press.

Mustika, P. L. K., Ichsan, M., & Booth, H. (2020). The Economic Value of Shark and Ray Tourism in Indonesia and Its Role in Delivering Conservation Outcomes. Frontiers in Marine Science, 7, 261.

O'Leary, B. C., Brown, R. L., Johnson, D. E., von Nordheim, H., Ardron, J., Packeiser, T., & Roberts, C. M. (2012). The first network of marine protected areas (MPAs) in the high seas: the process, the challenges and where next. Marine Policy, 36(3), 598-605.

Pham, C., Canha, A., Diogo, H., Pereira, J. G., Prieto, R., and Morato, T. (2013). Total marine fisheries catch for the Azores (1950-2010). ICES J. Mar. Sci. 70, 564–577. doi: 10.1093/icesjms/fst024

Pires, N. M., Garla, R. C., & Carvalho, A. R. (2016). The economic role of sharks in a major ecotourism archipelago in the western South Atlantic. Marine Policy, 72, 31-39.

Portney, P. R. (1994). The contingent valuation debate: why economists should care. Journal of Economic perspectives, 8(4), 3-17.

Queiroz, N., Humphries, N.E., Couto, A., Vedor, M., da Costa, I., Sequeira, A.M.M., Mucientes, G., Santos, A.M., Abascal, F.J., Abercrombie, D.L., Abrantes, K., Acuña-Marrero, D., Afonso, A.S., Afonso, P., Anders, D., Araujo, G., Arauz, R., Bach, P., Barnett, A., Bernal, D., Berumen, M.L., Bessudo Lion, S., Bezerra, N.P.A., Blaison, A.V., Block, B.A., Bond, M.E., Bonfil, R., Bradford, R.W., Braun, C.D., Brooks, E.J., Brooks, A., Brown, J., Bruce, B.D., Byrne, M.E., Campana, S.E., Carlisle, A.B., Chapman, D.D., Chapple, T.K., Chisholm, J., Clarke, C.R., Clua, E.G., Cochran, J.E.M., Crochelet, E.C., Dagorn, L., Daly, R., Devia Cortés, D., Doyle, T.K., Drew, M., Duffy, C.A.J., Erikson, T., Espinoza, E., Ferreira, L.C., Ferretti, F., Filmalter, J.D., Fischer, C.G., Fitzpatrick, R., Fontes, J., Forget, F., Fowler, M., Francis, M.P., Gallagher, A.J., Gennari, E., Goldsworthy, S.D., Gollock, M.J., Green, J.R., Gustafson, J.A., Guttridge, T.L., Guzman, H.M., Hammerschlag, N., Harman, L., Hazin, F.H.V., Heard, M., Hearn, A.R., Holdsworth, J.C., Holmes, B.J., Howey, L.A., Hoyos, M., Hueter, R.E., Hussey, N.E., Huveneers, C., Irion, D.T., Jacoby, D.M.P., Jewell, O.J.D., Johnson, R., Jordan, L.K.B., Jorgensen, S.J., Joyce, W., Keating Daly, C.A., Ketchum, J.T., Klimley, A.P., Kock, A.A., Koen, P., Ladino, F., Lana, F.O., Lea, J.S.E., Llewellyn, F., Lyon, W.S., MacDonnell, A., Macena, B.C.L., Marshall, H., McAllister, J.D., McAuley, R., Meÿer, M.A., Morris, J.J., Nelson, E.R., Papastamatiou, Y.P., Patterson, T.A., Peñaherrera-Palma, C., Pepperell, J.G., Pierce, S.J., Poisson, F., Quintero, L.M., Richardson, A., Rogers, P.J., Rohner, C.A., Rowat, D.R.L., Samoilys, M., Semmens, J.M., Sheaves,

M., Shillinger, G., Shivji, M., Singh, S., Skomal, G.B., Smale, M.J., Snyders, L.B., Soler, G., Soria, M., Stehfest, K.M., Stevens, J.D., Thorrold, S.R., Tolotti, M.T., Towner, A., Travassos, P, Tyminski, J.P., Vandeperre, F., Vaudo, J.J., Watanabe, Y.Y., Weber, S.B., Wetherbee, B.M., White, T.D., Williams, S., Zárate, P.M., Harcourt, R., Hays, G.C., Meekan, M.G., Thums, M., Irigoien, X., Eguiluz, V.M., Duarte, C.M., Sousa, L.L., Simpson, S.J., Southall, E.J., & Sims, D.W. (2019) Global spatial risk assessment of sharks under the footprint of fisheries. Nature, https://doi.org/10.1038/s41586-019-1444-4

Rathnayake, R. W. (2017). ECONOMIC VALUATION OF WILDLIFE TOURISM: "CONTINGENT VALUATION METHOD". Wilderness of Wildlife Tourism, 233.

Ressurreição, A., Gibbons, J., Dentinho, T. P., Kaiser, M., Santos, R. S., and Edwards-Jones, G. (2011). Economic valuation of species loss in the open sea. Ecol. Econ. 70,729–739. doi:10.1016/j.ecolecon.2010.11.009

Ressurreição, A., Gibbons, J., Kaiser, M., Dentinho, T. P., Zarzycki, T., Bentley, C., et al. (2012). Different cultures, different values: the role of cultural variation in public's WTP for marine species conservation. Biol. Conserv. 145,148–159. doi:10.1016/j.biocon.2011.10.026

Ressurreição, A., & Giacomello, E. (2013). Quantifying the direct use value of Condor seamount. Deep Sea Research Part II: Topical Studies in Oceanography, 98, 209-217.

Rigby, C.L., Barreto, R., Carlson, J., Fernando, D., Fordham, S., Francis, M.P., Herman, K., Jabado, R.W., Liu, K.M., Marshall, A., Pacoureau, N., Romanov, E., Sherley, R.B., & Winker, H. (2019a). Prionace glauca. The IUCN Red List of Threatened Species 2019: e.T39381A2915850. https://dx.doi.org/10.2305/IUCN.UK.2019-3.RLTS.T39381A2915850.en.

Rigby, C.L., Barreto, R., Carlson, J., Fernando, D., Fordham, S., Francis, M.P., Jabado, R.W., Liu, K.M., Marshall, A., Pacoureau, N., Romanov, E., Sherley, R.B., & Winker, H. (2019b). Isurus oxyrinchus. The IUCN Red List of Threatened Species 2019: e.T39341A2903170. https://dx.doi.org/10.2305/IUCN.UK.2019-1.RLTS.T39341A2903170.en.

Santos, R., Novoa-Pabon, A., Silva, H., & Pinho, M. (2020). Elasmobranch species richness, fisheries, abundance and size composition in the Azores archipelago (NE Atlantic). Marine Biology Research, 16(2), 103-116.

Schuhmann, P. W., Skeete, R., Waite, R., Lorde, T., Bangwayo-Skeete, P., Oxenford, H. A., Gill, D., Moore, W., & Spencer, F. (2019). Visitors' willingness to pay marine conservation fees in Barbados. Tourism Management, 71, 315-326.

Solomon, B. D., Corey-Luse, C. M., & Halvorsen, K. E. (2004). The Florida manatee and eco-tourism: toward a safe minimum standard. Ecological Economics, 50(1-2), 101-115.

Stithou, M., & Scarpa, R. (2012). Collective versus voluntary payment in contingent valuation for the conservation of marine biodiversity: an exploratory study from Zakynthos, Greece. Ocean & coastal management, 56, 1-9.

Topelko, K. N., & Dearden, P. (2005). The shark watching industry and its potential contribution to shark conservation. Journal of Ecotourism, 4(2), 108-128.

Torres, P., da Cunha, R. T., & dos Santos Rodrigues, A. (2016). The elasmobranch fisheries of the Azores. Marine Policy, 73, 108-118.

Torres, P., Bolhão, N., da Cunha, R. T., Vieira, J. A. C., & dos Santos Rodrigues, A. (2017). Dead or alive: The growing importance of shark-diving in the Mid-Atlantic region. Journal for nature conservation, 36, 20-28.

Venkatachalam, L. (2004). The contingent valuation method: a review. Environmental impact assessment review, 24(1), 89-124.

Vianna, G. M. S., Meekan, M. G., Pannell, D., Marsh, S., & Meeuwig, J. J. (2010). WANTED DEAD OR ALIVE? The relative value of reef sharks as a fishery and an ecotourism asset in Palau. Australian Institute of Marine Science, Perth.

Vianna, G. M. S., Meeuwig, J. J., Pannell, D., Sykes, H., & Meekan, M. G. (2011). The socioeconomic value of the shark-diving industry in Fiji. Perth: University of Western Australia. 26p.

Vianna, G. M. S., Meekan, M. G., Pannell, D. J., Marsh, S. P., & Meeuwig, J. J. (2012). Socio-economic value and community benefits from shark-diving tourism in Palau: a sustainable use of reef shark populations. Biological Conservation, 145(1), 267-277.

Vianna, G. M., Meekan, M. G., Rogers, A. A., Kragt, M. E., Alin, J. M., & Zimmerhackel, J. S. (2018). Shark-diving tourism as a financing mechanism for shark conservation strategies in Malaysia. Marine Policy, 94, 220-226.

Vieira, J., Câmara, G., Silva, F., & Santos, C. (2019). Airline choice and tourism growth in the Azores. Journal of Air Transport Management, 77, 1-6.

Ward-Paige, C. A. (2017). A global overview of shark sanctuary regulations and their impact on shark fisheries. Marine Policy, 82, 87-97.

White, P. C., Bennett, A. C., & Hayes, E. J. (2001). The use of willingness-to-pay approaches in mammal conservation. Mammal Review, 31(2), 151-167.

Whitehead, J. C. (1992). Ex ante willingness to pay with supply and demand uncertainty: implications for valuing a sea turtle protection programme. Applied Economics, 24(9), 981-988.

Worm, B., Davis, B., Kettermer, L., Ward-Paige, C.A., Chapman, D., Heithaus, M.R., Kessel S.T. & Gruber, S. H. (2013). Global catches, exploitation rates, and rebuilding options for sharks. Marine Policy, 40, 194-204.

Worm, B. (2017). Marine conservation: how to heal an ocean. Nature, 543(7647), 630-631.

Xiao, J., Wang, M., & Gao, X. (2020). Valuing tourists' willingness to pay for conserving the non-use values of marine tourism resources: a comparison of three archipelagic tourism destinations in China. Journal of Sustainable Tourism, 1-33.

Zimmerhackel, J. S., Rogers, A. A., Meekan, M. G., Ali, K., Pannell, D. J., & Kragt, M. E. (2018). How shark conservation in the Maldives affects demand for dive tourism. Tourism Management, 69, 263-271.

Zimmerhackel, J. S., Kragt, M. E., Rogers, A. A., Ali, K., & Meekan, M. G. (2019). Evidence of increased economic benefits from shark-diving tourism in the Maldives. Marine Policy, 100, 21-26.

CHAPTER 3

A CONCEPTUAL MODEL FOR ASSESING POTENTIAL SITES FOR THE DEVELOPMENT OF SHARK-DIVING TOURISM

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CHAPTER 3

A conceptual model for assessing potential sites for the development of shark-diving tourism

Abstract

Sharks are widely distributed throughout the world's oceans, which presents many opportunities for the development of shark-diving tourism. A crucial step in tourism planning process is the evaluation of attributes at potential locations prior to tourism development. In this study, we provided a review of the sites where shark-diving tourism is known to occur, and analyze these sites for common attributes. Using a weighted linear combination ranking technique, we employed a multi-attribute decision making to establish the shark-diving potential value of the existing sites. A total of 125 shark-diving sites were identified with 6 common attributes associated to them (abundance, seasonality, water visibility, diver level requirement, accessibility, and legal protection). We used this information to build a conceptual model for identifying and assessing the potential of new sites for the development of shark-diving tourism. We further applied our conceptual model to the Canary Islands as a case study using data from the literature and interviews conducted with stakeholders from the diving industry, academia, NGO's and regional government. We identified 24 sites with high potential for development of shark-diving tourism in the Canary Islands. Our conceptual model could help to guide government authorities and policy makers to identify and provide a preliminarily assessment of shark-diving sites with potential for development. This could serve to regulate tourism operating licenses, implement adequate tourism planning processes and potentially improve coordination of the actions required to bring economic benefits to the local communities that can benefit from this industry, and support shark conservation through shark-diving tourism development.

Keywords: Shark-based tourism; Tourism potential; Shark conservation; Wildlife tourism; Macaronesian archipelagos

1. Introduction

Shark-diving tourism is a growing industry around the world. In 2011, it was estimated that nearly 600,000 participants were engaged in this activity, with this number potentially reaching 1,5 million in the next decade (Cisneros-Montemayor et al., 2013). This industry has contributed significantly to several coastal economies (Topelko and Dearden, 2005; Gallagher and Hammerschlag, 2011; Vianna et al., 2011; Haas et al., 2017; Huveneers et al., 2017; Mieras et al., 2017; Zimmerhackel et al., 2019) and provides strong incentives for shark conservation strategies (Vianna et al., 2018). In certain cases, it has been provided a new paradigm for viewing sharks as a socio-economically attractive non-consumptive resource when compared to fishing (Vianna et al., 2010; Gallagher & Hammerschlag, 2011, Gallagher & Huveneers, 2018). In the view of these benefits, the shark-diving tourism industry has drawn academic attention and the scientific literature suggests further research on the identification and assessment of new potential locations for shark-diving tourism development (Topelko & Dearden, 2005; Cisneros-Montemayor et al., 2013).

A global study performed by Gallagher & Hammerschlag (2011) revealed 83 shark-diving locations in 2010; however, this number could have potentially increased in the last decade (Cisneros-Montemayor et al., 2013). Shark divers worldwide are drawn to dive destinations where sharks can be encountered on a consistent basis and observed at close range, preferably in clear waters such as Tiger Beach in the Bahamas or Beqa Lagoon in Fiji (Topelko & Dearden, 2005). However, shark-diving operations vary according to locations and species being viewed, whereby, to be successful, a basic understanding of shark moving patterns and behavior is required (Topelko & Dearden, 2005). For example, whale sharks (*Rhincodon tipus*) can be reliably sighted at certain locations along their migration routes, such as Ningaloo Reef, Philippines or Mexico (Catlin et al., 2012; Indab, 2016; Ziegler et al., 2012). In other cases, dive operators use bait to attract sharks. In Australia and South Africa, for example, great white sharks (*Carcharodon carcharias*) are usually lured by the chum released gradually into the water in order to provide the best opportunity for divers to see these predators close by from cages.

In the present paper, we revised all the existing shark-diving sites, identifying the common attributes to these sites and ranked these attributes by importance. We used this to develop a conceptual model to assess the potential of any given site for the development of shark-diving tourism based on empirical observations of their attributes. As a case study, we applied our model to identify and assess potential sites for shark-diving tourism development in the Canary Islands. This archipelago is among most popular coastal tourism destinations in Europe with several visitors engaging in recreational diving activities (Gonzáles-Mantilla et al., 2021). While angel sharks (*Squatina spp.*) are one of the most commonly encountered species (Baker et al., 2016), little is known about the potential of development of a shark-diving industry in the archipelago. Combining an extensive literature review and interviews with tourism, academic and government actors in the archipelago using semi-structured questionnaires, we provide an overview of the perspectives and opportunities for potential shark-diving tourism development in the Canary Islands.

2. Methods

2.1. Examination of existing shark-diving sites around the world and their attributes

Our examination was conducted from January to May 2021 using a three-stage process. Firstly, we identified all the established shark-diving sites based on two global reviews (Gallagher & Hammerschlag, 2011; Healy et al., 2020). Then, we performed an extensive search on peer-reviewed publications through Web of Science and Google Scholar using the keywords "shark-diving tourism", "shark watching", "shark ecotourism", "shark-based tourism" and "shark tourism", followed by Internet websites search using the keywords "shark diving", "shark tourism", "swimming with sharks", "snorkeling with sharks", "shark cage", "shark tour" and "shark adventure" on each shark-diving location. This two-step search aimed to validate if the shark-diving industries were still active and to identify new emerging sites. We selected those shark-diving sites where dive operators advertised reliable encounters with sharks and excluded locations where encounters were only opportunistic. Components of an operation that met this criterion generally included promotion and pricing of specific shark-related activities, and descriptions citing sharks as the target attraction of a given diving or snorkeling activity. Based on this search, we compiled a list of all the existing shark-diving sites around the world.

In the second stage we identified and described the common attributes of existing shark-diving sites. We defined common attributes as the specific features generally advertised by dive operators in order to describe the shark-diving experience promoted. We identified these attributes in most of the dive operators' websites operating on each site. Then, we ranked each attribute from Low (1) to High (3). Our criteria to establish a rank was based on personal inquiries to shark-diving experts (e. g.; Less than 10 meters: Low visibility). Finally, we classified the attributes into the following categories: natural attributes, tourism related attributes and conservation related attributes.

2.2. Conceptual model framework

Based on the most common attributes of the shark-diving sites identified, we built a conceptual model to assess the potential of a site for the development of shark-diving tourism. Firstly, we stablished a system to indicate the importance of each category of attributes and each attribute (from 1-Low to 3-High) to provide the adequate conditions for a site to potentially development of a shark-diving industry. To do this, we defined the attributes and categories' importance based on the highest ranked attributes in our global analysis of shark-diving sites and factors of attraction derived from the literature (e.g. Topelko & Dearden, 2005; Gallagher et al., 2015). We then employed a multicriteria evaluation approach using a weighted linear combination technique for each category and attribute. This methodological framework evaluates the tourism potential of specific regions based on the facilities available and existing natural and socio-cultural attributes (Malik & Bhat, 2015). These attributes were used as indicators which were linearly combined assigning relative weightings to them. In our study, categories and attribute weights were used as indicators and sub-indicators of the potential of a site for development of shark-diving tourism, respectively. The weights were normalized so that the sum of normalized weights is equal to unity.

An ordinal scale was adopted to rank each sub-indicator from 1-Low to 3-High. For coding, values were assigned to each category: 0.2 for the lowest value, 0.6 (intermediate value), and 1 (highest

value) (Al Mamun & Mitra, 2012; Yan et al., 2017). The computation of the shark-diving potential value was calculated with the following formula:

$$SDPV = \sum Wj \left(\sum w_{ii} * s_j\right) \quad (1)$$

Where SDPV is the shark-diving potential value, Wj is the normalized weight of the indicators, w_{ji} is the normalized weight of sub-indicators in the *j*-th indicator set, and s_i is the scale of sub-indicator.

We tested our model by estimating the shark-diving potential value of all existing shark-diving sites with the aim to stablish a ranking of probability to become a shark-diving site, we considered the lowest valued site as the minimum value required for new sites to be classified as a viable site for development of shark diving.

2.3. Case study: The Canary Islands

Study area

The Canary Islands are an archipelago consisting of eight islands in the Atlantic Ocean: El Hierro, La Palma, La Gomera, Tenerife, Gran Canaria, Fuerteventura, Lanzarote and La Graciosa. It is an autonomous region of Spain located 1,300 km away from the Spanish mainland and with the easternmost island being just 100 km from the African coast. They are also one of the outermost regions of the European Union and part of the Macaronesian biogeographic region. Tourism is the main economic activity of the Canary Islands and represented 35% of the GDP in 2018. The archipelago receives around 15 million of visitors annually, 89% of which come from the main European outbound tourism countries and 11% from the Spanish mainland. There are four main tourism islands, Tenerife (5.8 million tourists in 2018); Gran Canaria (4.4 million); Lanzarote (2.9 million) and Fuerteventura (2.1 million).

The Canary Islands are a very popular tourist destination for scuba divers, mainly El Hierro, Fuerteventura, Gran Canaria, Lanzarote and Tenerife (Meyers et al., 2017). In 2019, 145 diving centers distributed across the archipelago were identified, of which 108 advertised opportunistic shark encounters (Gonzáles-Mantilla et al., 2021). In our study we focused on the islands where dive centers have reported shark encounters (Gonzáles-Mantilla et al., 2021): El Hierro, Tenerife, Gran Canaria, Fuerteventura, Lanzarote and La Graciosa.

Interviews

In order to apply our model in the Canary Islands we collected primary information about the potential sites for shark-diving tourism development and their attributes through semi-structured interviews with Canarian stakeholders. From June to November 2021, we conducted these interviews with dive operators, marine scientists and regional government authorities. Our criteria to select these local stakeholders was whether their job was related to the Canarian marine environment and specifically to sharks and included: a) presence of dive operators that advertised opportunistic shark encounters (Gonzáles-Mantilla et al., 2021); b) Non-governmental organizations leading shark conservation projects and marine scientists currently working with shark populations research in the archipelago; and c) government authorities of tourism and marine conservation. Dive companies were previously identified in Gonzáles-Mantilla et al. (2021). NGO's and marine scientists were identified through internet research using keywords such as "shark study" or "shark research" in the Canary Islands. We also used snowball sampling to identify other marine scientists and government authorities.

Interviews were conducted face-to-face and based on a semi-structured questionnaire covering the following aspects: potential development of shark-diving tourism in the Canary Islands and

potential sites for shark-diving tourism. Then, according to the experience of each interviewee, we addressed the main common attributes identified in our examination regarding the Canary Islands and they were asked to rank each attribute.

3. Results

3.1. Overview of the shark-diving sites around the world

Our examination revealed 125 shark-diving sites distributed in 39 countries and 13 ocean regions: Eastern Central Pacific, Eastern Indian Ocean, Mediterranean and Black Sea, Northeast Atlantic, Northeast Pacific, Northwest Atlantic, Northwest Pacific, Southeast Atlantic, Southeast Pacific, Southwest Pacific, Western Central Atlantic, Western Central Pacific, Western Indian Ocean. Most of shark-diving sites are located in Western Central Pacific (25%), followed by Western Indian Ocean (21%) and Western Central Atlantic (13%). Regarding countries' distribution, Mexico has the highest number of shark-diving sites with 11 sites, followed by USA with 10 and then Australia, Philippines and Palau with 7 sites each.

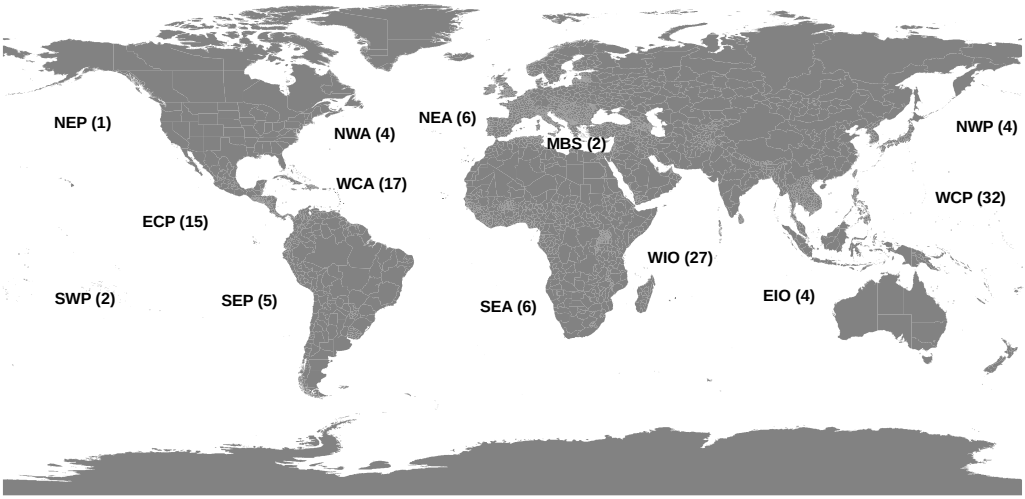

Figure 1. Global distribution of shark-diving sites by ocean regions. ECP: Eastern Central Pacific, EIO: Eastern Indian Ocean, MBS: Mediterranean and Black Sea, NEA: Northeast Atlantic, NEP: Northeast Pacific, NWA: Northwest Atlantic, NWP: Northwest Pacific, SEA: Southeast Atlantic, SEP: Southeast Pacific, SWP: Southwest Pacific, WCA: Western Central Atlantic, WCP: Western Central Pacific, WIO: Western Indian Ocean.

We identified 37 shark species providing reliable encounters in the shark-diving sites around the world. The grey reef shark (*Carcharhinus amblyrhynchos*) is the most commonly encountered specie (34 sites), followed by whale sharks (*Rhincodon typus*) in 29 sites, whitetip reef sharks (*Triaenodon obesus*) in 27 sites and scalloped hammerhead sharks (*Sphyrna lewin*i) in 23 sites. The shark-diving sites with the highest number of shark species encountered were Fuvahmulah Atoll in Maldives, and Palm Beach in Florida, USA (8 shark species each). These were followed by Gardens of the Queen Marine Park in Cuba, and Pinnacles reef in Ponta do Ouro Partial Marine Reserve, Mozambique, with 7 shark species, and Shark Reef Marine Reserve in Fiji, Derawan Islands in Indonesia, and Protea Banks in South Africa, with 6 shark species each.

Scuba diving was the most common activity in the shark-diving sites around the world (75%), followed by snorkeling (34%) and cage diving in 6%. We also found that in almost 13% of all the shark-diving sites scuba diving and snorkeling were both advertised activities by dive operators. Only in 3% of them, all these activities were available.

We also identified three methods for shark encounters used by dive operators in the global shark-diving sites: natural aggregation, provisioning (feeding and baiting) and non-consumable attractant (mammal-shaped decoy and sound). Dive operations in natural aggregation sites were the most common (80%), followed by provisioning in 34 sites and non-consumable attractant in 1 dive site. We also found that in 10 sites 2 methods existed: Natural aggregation and provisioning.

3.1.1. Attributes

We identified 6 common attributes in all the existing shark-diving sites: abundance, seasonality, visibility, diver level requirement, accessibility, and legal protection. We classified them into the following categories: natural attributes, tourism related attributes and conservation related attributes (Table 1).

Table 1. Categories, attributes and their classification in the shark-diving sites around the world

Categories	Attributes	Classification
Natural attributes	Abundance	"Low", when less than 3 individuals were observed; "Intermediate", from 3 to 10 individuals; and "High", when more than 10 individuals were regularly observed
	Seasonality	"Seasonal", when dive operations occur less than 6 months per year and "Year-Round" when these operations occur more than 6 months per year.
	Visibility	"Low", when visibility goes from 0 to 10 meters; "Intermediate", from 11 to 20 meters; and "High", beyond 20 meters
Tourism related attributes	Diver level requirement	"Basic", when Open Water certificate is needed; "Intermediate", when a "Basic" with minimal number of dives is required; and "Advanced", when an Advanced certificate or higher level is needed.
	Accessibility	"High", when less than 1-hour trip was needed; "Intermediate", from 1-hour to 3-hours trip; and "Low", when more than 3-hours trip or access only via liveaboard were required
Conservation related attributes	Legal protection	"Yes" if the dive site is included in an area under national protection.

3.1.1.1. Natural attributes

Abundance

We identified different abundance level on the average number of sharks reported regularly in each dive site. Abundance was classified as "High" in 56% of shark-diving sites around the world, while the rest of them (44%) were classified as "Intermediate" (Supplementary material).

Seasonality

We identified 72 shark-diving sites where shark encounters occur all year-round (nearly 58%), while in the rest of them reliable encounters were seasonable. We considered as "Year-round" when any shark specie is encountered in each dive site.

Visibility

We identified different underwater visibility levels in the shark-diving sites. Nearly 54% of the global shark-diving locations had "Intermediate"" visibility; 40% was categorized as "High" and barely 6% had "Low" visibility.

3.1.1.2. Tourism related attributes

Diver level requirement

We identified different diver levels required to engage shark-diving operations in all the existent shark-diving sites. "Basic" and "None required" were the most common diver levels needed with 39 and 33%, respectively. While 18% of the shark-diving sites required an "Intermediate" level and 26% an "Advanced" level. In some cases, there were more than 1 diver level required according to the season or type of activity in the respective shark-diving site.

Accessibility

We identified different accessibility levels to the shark-diving sites from mainland. Most of the shark-diving sites had a "High" level of accessibility (68%), while 23% and 9% had "Intermediate" and "Low" levels, respectively.

3.1.1.3. Conservation related attributes

Legal protection

We found that over 54% of the global shark-diving sites are included into national protected areas. We excluded "Biosphere reserves" as we could not define them as a whole legal protected area. In order to identify which areas are under national protection we used the keywords "marine reserve" and/or "marine protected area" on each dive site in our Internet websites search.

3.2. Conceptual model framework

Based on the analysis of the common attributes in the 125 shark-diving sites, we stablished weights to the 3 categories and 6 attributes (Table 2). Natural attributes were considered the most important category as this reflects the attractiveness of the location for diving with sharks (3-High), followed by tourism-related attributes as this shows the conditions to engage shark-diving activities. Abundance and accessibility were considered the highest valued attributes as in all the shark-diving sites was possible to observe beyond 3 individuals on average and in 91% of the locations the time required to arrive from the mainland was below 3 hours, and in 2 out of 3 locations the time needed to arrive was lower than 1 hour. Seasonality, visibility and legal protection were ranked as the second highest ranked attributes (2-Intermediate) as these were

considered important features of a shark-diving site (Year-round seasonality, Intermediate visibility and legal protected area: > 50%). Finally, Diver level requirement was the lowest ranked attribute (1) since in most of the sites (66%) basic level or none-experienced divers were allowed to engage shark-diving activities. The overarching criterion is further developed in the Discussions.

Table 2. Weights of indicators and sub-indicators used for assessment of potential sites for shark-diving tourism

Indicator	Weight	Normalized weight	Sub-indicator	Weight	Normalized weight
Natural attributes	3	0.5	Abundance	3	0.42
			Seasonality	2	0.29
			Visibility	2	0.29
Tourism-related attributes	2	0.33	Diver level requirement	1	0.25
			Accessibility	3	0.75
Conservation-related attributes	1	0.17	Legal protection	2	1

We applied our formula (1) in all the shark-diving sites we previously identified. The scale selected to each sub-indicator was similar to that we used in our analysis of attributes from 1-Low (0.2), 2-Intermediate (0,6) and 3-High (1) in Abundance, Visibility and Accessibility. Regarding Diver level requirement, we considered that “None required” and “Basic” as 3-High (1), Intermediate as 2-Intermediate (0.6) and Advanced as 1-Low (0.2). Regarding Seasonality and Legal protection, we considered “Year-round” as 3-High (1) and “Seasonal” as 2-Intermediate (0.6), and “Yes” as 3-High (1) and “No” as 2-Intermediate (0.6), respectively. We presented the results of shark-diving potential value (SDPV) of some of the most reckon shark-diving sites around the world in Table 3.

Table 3. Shark-diving potential value of popular shark-diving sites around the world

Dive site	Abundance	Seasonality	Visibility	Diver level	Accessibility	Legal protection	SDPV
Sipadan Island Park, Sabah, Malaysia	1	1	1	1	1	1	1
Shark Reef Marine Reserve, Beqa Lagoon, Viti Levu, Fiji	1	1	1	0.6	1	1	0.97
Tiputa Pass, Rangiroa, French Polynesia	1	1	1	1	1	0.6	0.93
Bimini, The Bahamas	0.6	1	1	1	1	1	0.92
Gordon Rocks, Galapagos Marine Reserve, Ecuador	1	1	0.6	0.6	1	1	0.91
Ningaloo Reef Marine Park, Western Australia, Australia	1	0.6	0.6	1	1	1	0.88
Shark Observatory, Ras Mohammed National Park, Egypt	1	0.6	1	0.6	1	1	0.88
Cocos Island National Park, Costa Rica	1	1	1	1	0.2	1	0.80
Mossel Bay, Garden Route, South Africa	0.6	1	0.2	1	1	0.6	0.73

Providencia in Colombia, Sipadan Island Park in Malaysia, New Drop Off and Ngerchong Wall in Palau, and Shark Wall, The Arena and The Runaway in Bahamas, were the highest valued locations (1). Cornwall and Plymouth in England (0.575) and Farallones National Marine Sanctuary in USA (0.544) were the lowest valued locations.

Based on our results of shark-diving potential value in all the existent shark-diving sites (Supplementary material), we stablished a ranking of potential probability for shark-diving tourism development: Unknown (< 0.54), Likely (0.54 - 0.69), Very likely (0.7 - 0.85) and Highly likely (0.86 - 1).

3.3. Overview of shark-diving tourism potential in the Canary Islands, as synthesized of our interviews

We obtained information to assess the shark-diving tourism potential in the Canary Islands based on the interviews conducted with 30 stakeholders: 21 dive operators, 5 marine scientists and 4 government authorities. Overall, we found that the Canary Islands has a great potential for shark-diving tourism development mainly targeting two species: angel shark (*Squatina spp.*) and blue shark (*Prionace glauca*). Shortfin mako shark (*Isurus oxyrinchus*), smalltooth sand tiger shark (*Odontaspis ferox*), and hammerhead sharks (*Sphyrna couardi and zygaena*) are also potential target species for dedicated shark-diving operations. Yet, the number of target species could increase as climate change effect may trigger appearance of new tropical shark populations in the Canarian waters. Information gathered by marine scientists show that migratory shark species such as blue shark, short fin mako shark and hammerhead sharks are usually found in the offshore waters of most of the islands from July to November. Tope shark (*Galeorhinus galeus*) and silky shark (*Carcharhinus falciformis*) are also commonly observed in the Canary Islands. However, these species were not recommended for shark-diving activities since the first they are usually

found in low visibility waters by short periods and the second they are frequently observed near to fish farms which could alter their behavior, increasing risk of aggression toward humans.

According to dive operators there is an emerging tourist demand for shark-diving encounters and angel shark is one of the most popular among recreational dive tourists. Also, new dive companies have shown interest to invest in dedicated shark-diving operations with blue and mako sharks using chumming in offshore waters, similar to Bermeo, Spain or the Azores Islands (Gonzáles-Mantilla et al., 2022). However, government authorities have denied their tourism operating license arguing potential human risk. Most of the interviewees agree with this decision contending that there is a need of planning to avoid negative impact of overload tourism. Yet, they also highlight the lack of knowledge of government authorities on potential benefits of shark-diving tourism for the Canarian archipelago. All conclude that there is a need to further develop academic research on the biology and ecology of shark populations in the Canary Islands to better understand their movement patterns and behavior. This relevant information could serve as a guide for potential tourism activities. They also highlight the need of legal protection of all shark species in Canarian waters and implementation of new marine protected areas (MPA).

3.3.1. Potential shark-diving sites and their shark-diving potential value (SDPV)

We identified 24 potential sites for shark-diving tourism development in the Canary Islands distributed in six islands: El Hierro, Tenerife, Gran Canaria, Fuerteventura, Lanzarote y La Graciosa (Fig. 2). Fuerteventura presents the highest number of potential shark-diving sites with 7, followed by Tenerife and Gran Canaria with 5. Angel shark is the most potential target specie for shark-diving tourism development in the Canary Islands accounting for 17 potential sites and distributed in five islands. Mar de las Calmas Marine Reserve in El Hierro is the potential site with highest number of potential target shark species (4), followed by Teno-Rasca in Tenerife (3) and Alegranza in La Graciosa (2).

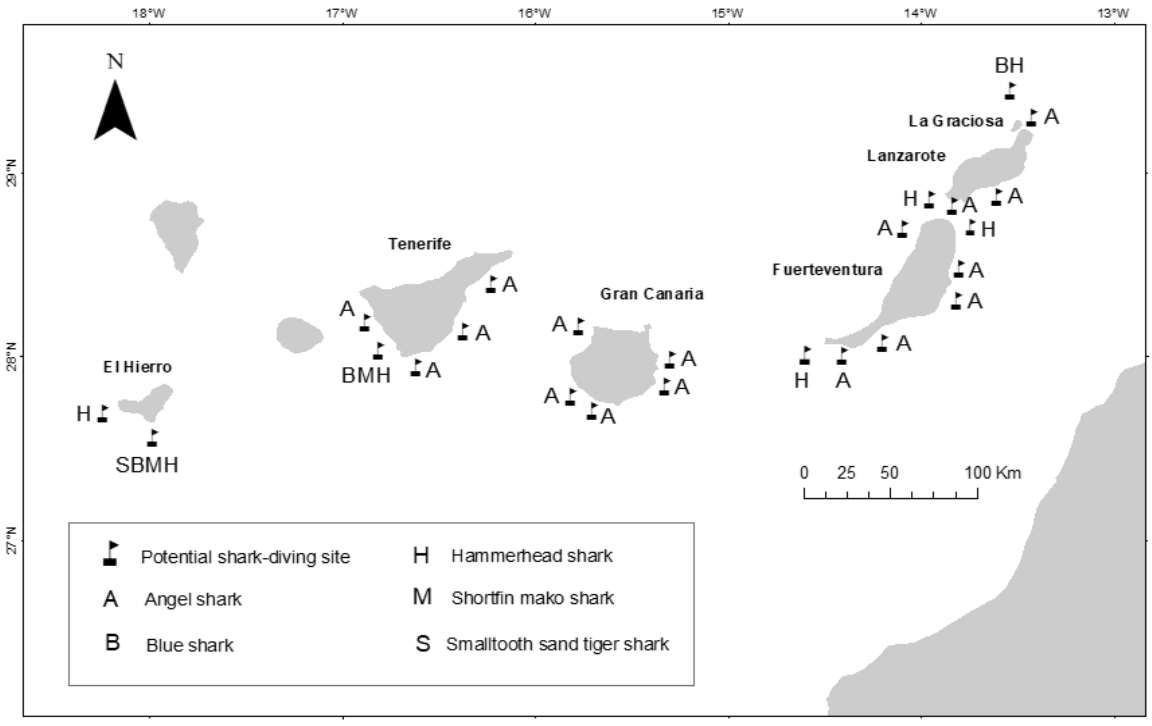

Figure 2. Potential sites and target species for shark-diving tourism development in the Canary Islands

Teresitas in Tenerife and La Graciosa Marine Reserve in La Graciosa were the potential sites with highest SDPV, whilst Faro de Orchilla in El Hierro and Lobos Island in Fuerteventura were the least valued (Table 4). Most of potential shark-diving sites (57%) present a Very Likely probability to become a shark-diving site, followed by Highly Likely in 23% of all potential sites. Some of the stakeholders indicate that Banco de Concepcion in Lanzarote could be a potential shark-diving site mainly due to the presence of blue, shortfin mako and hammerhead sharks; however, we did not include this site in our list as its SDPV was below the minimum required (0.37).

Table 4. Shark-diving potential value of potential shark-diving sites in the Canary Islands

Island	Dive site	Abundance	Seasonality	Visibility	Diver level requirement	Accesibility	Legal protection	SDPV
El Hierro	Mar de Las Calmas Marine Reserve	0.2	0.6	1	0.2	1	1	0.71
	Faro de Orchilla	0.6	0.6	0.6	0.2	0.6	0.6	0.57
Tenerife	Abades	0.6	0.6	1	1	1	1	0.86
	Teresitas	1	1	0.2	1	1	1	0.88
	Gigantes	0.2	0.6	1	0.2	1	0.6	0.64
	Galletas	0.6	0.6	1	0.2	1	0.6	0.72
	Teno-Rasca	0.6	0.6	1	0.2	0.6	1	0.69
Gran Canaria	Sardina	1	0.6	1	1	1	0.6	0.87
	El cabron	1	0.6	1	1	0.6	0.6	0.78
	Tufia	0.6	0.6	1	1	1	0.6	0.79
	Amadores	0.6	0.6	1	1	1	0.6	0.79
	Mogan	0.6	0.6	1	1	1	0.6	0.79
Fuerteventura	Morro jable/Jandia	1	0.6	1	1	1	0.6	0.87
	Puerto del rosario	0.6	0.6	1	1	1	0.6	0.79
	Lajita	0.6	0.6	1	1	1	0.6	0.79
	Castillo	1	0.6	1	1	1	0.6	0.87
	Cotillo/La concha	0.6	0.6	0.6	1	1	0.6	0.73
	Lobos Island	0.6	0.6	0.6	0.2	0.6	0.6	0.57
	Baja de Amanay	0.6	0.6	1	0.2	0.6	1	0.69
Lanzarote	Playa chica	1	0.6	0.6	1	1	0.6	0.82
	Playa dorada	0.6	0.6	0.6	1	1	0.6	0.73
	Pechiguera	0.2	0.6	1	0.2	1	1	0.71
La Graciosa	La Graciosa Marine Reserve	1	0.6	0.6	1	1	1	0.88
	Alegranza Island	0.6	0.6	1	0.2	0.6	1	0.69

4. Discussions

4.1. Global analysis of shark diving-sites

Our global analysis shows that the number of existent shark-diving sites has increased 50% in the last decade when compared to Gallagher & Hammerschlag (2011). This could be explained by the rapid expansion of shark-diving industries and increasing interest on shark-diving experiences around the world (Cisneros-Montemayor et al., 2013). The Western Central Pacific Ocean is still the leading region on number of shark-diving sites which is also reflected on increasing academic attention (Gallagher et al., 2015). This could also be explained by the favorable settings which characterized these diving sites such as clear water visibility, high abundance and diversity of species, tourism development and establishment of shark marine reserves (Brunnschweiler, 2009; Vianna et al., 2011, 2012; Clua et al., 2011). The richness of marine wildlife species on Mexican waters, including shark species (Cisneros-Montemayor et al., 2020), could also explain their high proportion of shark-diving sites. Furthermore, Mexico has a vast coastline and privileged geographical position surrounded by Pacific Ocean, Gulf of Mexico, Caribbean Sea and Gulf of California. The latter is also known as Sea of Cortez which is considered an UNESCO World Natural Heritage and one of the most reckon dive destinations for white shark encounters (e.g. Guadalupe Island, Cisneros-Montemayor et al., 2020). The USA is also characterized by its large coastline surrounded by Gulf of Mexico, Atlantic and Pacific Oceans, and some locations with high diversity of shark species (e.g. Palm Beach, Florida), which is reflected in the high proportion of shark-diving sites on their waters.

The global shark-diving industry relies on 37 shark species which represented over 7% of all shark species existent. This number has doubled in the last years when compared to past studies (Dulvy et al., 2017) which also reflects the rapid global growth of the shark-diving tourism. The Grey reef shark (*Carcharhinus amblyrhynchos*) is the most popular target specie of all global shark-diving operations, probably due to its size, abundance and behavior (Vianna et al., 2012). Concomitant with the Whitetip reef shark (*Triaenodon obesus*), these two species are the most commonly encountered shark species in the Western Central Pacific (Ward-Paige et al., 2020), which accounted for the majority of shark-diving sites in the world. Whale sharks (*Rhincodon typus*) are also very popular among shark-diving operations mainly due to their large size, docile nature, predictable presence and accessibility (Ziegler & Dearden, 2021). These are the tourism target specie most globally distributed, spanning 7 ocean regions: Northwest Pacific, Southeast Pacific, Western Central Atlantic, Western and Eastern Indian Oceans, and Western and Eastern Central Pacific. Thus, it is not surprising that whale shark tourism has become one of the fastest growing sectors of the marine wildlife tourism industry overall (Gallagher & Hammerschlag, 2011). Scalloped hammerhead shark (*Sphyrna lewin*i) is also very common in global shark-diving operations being advertised in 18% of all shark-diving sites. This could also be explained by the wide presence of hammerhead sharks as target species in diverse ocean regions: Eastern Central Pacific, Southeast Pacific, Northwest Pacific, Western Central Atlantic and Western Indian Ocean.

The most popular species for shark-diving operations share common patterns related to predictable spatial and temporal aggregations as observed by Healey et al. (2020), which could explain that most of shark-diving sites relies on natural aggregations' method (80%). The other most popular method to attract sharks is provisioning which accounted for 27% of all shark-diving sites. Despite its complexity and variability of management regimes of quality control among locations (Meyer et al., 2021), provisioning has proved to be a very effective method for up-close view of sharks. However, development of new methods fewer complex could potentially expand the global shark-diving industry and strength sustainable management of shark-diving operations.

4.2. Attributes and conceptual model

Shark-diving sites may have a few common attributes, which potentially define their viability for the development for a shark-diving industry. Natural attributes such as abundance and visibility were categorized as the highest ranked attributes in our analysis as they play a key role for attracting shark divers worldwide (Topelko & Dearden, 2005). Furthermore, these attributes concomitant with proximity are generally ranked as the most influent motivations for tourists and/or the highest valued aspects of experience's satisfaction (Ziegler et al., 2012; Apps et al., 2017; Gonzáles-Mantilla et al., 2022). Evidence of increasing demand for dive trips when abundance of sharks is higher (Zimmerhackel et al., 2019) could potentially explain why abundance is the most important aspect among all attributes. Seasonality is also an important factor to assess shark-diving potential of a specific location since a longer period of shark-diving operations could result in a higher presence of dive tourists and benefits of shark-diving industries in terms of conservation and local economy could be increased particularly in small-islands which highly rely on marine tourism activities (e.g. Fiji or Palau).

In our model we considered tourism related attributes such as accessibility and diver level the second most important group for assessing shark-diving tourism potential of a shark-diving site; however, accessibility's weight was equally ranked as abundance since it is also a crucial factor to influence tourists to make a travel decision (Litman, 2003). For example, diving sites such as Garden of the Queen Marine Park, in Cuba, or Cocos Island National Park in Costa Rica, present a high abundance of sharks but accessibility is restricted to liveaboard transport which could limit access to shark-diving tourists. A high accessibility to a shark-diving site tends to enhance the site's attractiveness and attract tourists to visit and, subsequently, this attractiveness will also enhance tourists' satisfaction (Apps et al., 2017). Diver level requirement is also a determinant factor for shark-diving tourists' decision to choose a shark-diving site since this could also limit their possibilities to engage shark-diving experience (e.g. only Dive master in Kemoad Shoal, Philipines).

As shark-diving tourism relies on the creation of marine protected areas and enforcement of appropriate management regimes since this could ensure a high abundance of sharks and tourist's satisfaction (Zimmerhackel et al., 2018), legal protection is an important aspect to consider for assessing shark-diving tourism potential. Marine Protected Areas are a widely used tool for the protection of biodiversity and are increasingly advocated as a strategy for protecting or restoring shark and ray populations worldwide (Davidson & Dulvy, 2017; Gallagher et al., 2020). Shark-diving sites included in Biosphere Reserves were not considered legal protected in our analysis as many of them were not located in the core zone and further due to an overall lack of legal frameworks, policy, and regulations in these areas (Barraclough et al., 2021).

The results of shark diving potential value (SDPV) show that the most ranked shark-diving sites compound some of the most important shark-diving industries in the world (Table 3). However, we understand that new potential shark-diving sites identified through our conceptual model would not ensure that shark-diving tourism would bring their benefits in terms of conservation and increasing local income. Our ranking of shark-diving potential value is limited to measure the probability of a site to become an industry excluding other important evaluation aspects such as potential economic impact, management and risk (e.g. Healy et al., 2020).

Our global analysis has contributed to identify which attributes are commonly advertised in shark-diving sites and to estimate the level of importance of each attribute based on their global dominance. However, we realize that the nature of the concept of importance could trigger a lack of consistency in our analysis. Future studies could further develop the ranking of indicators and sub-indicators through enquiries to experts, who could help to improve the reliability of the

ranking because of their expertise and professional knowledge as suggested by Yan et al. (2017). The Multicriteria evaluation approach applied in our conceptual model has been a useful tool to shift our qualitative data in a quantitative estimation of the potential for shark-diving tourism development and could potentially guide us to identify and assess new locations for this emerging industry.

4.3. Shark-diving tourism potential in the Canary Islands

The Canary Islands are a popular destination for diving tourism in Europe and the most developed diving industry among Macaronesian archipelagos (Gonzáles-Mantilla et al., 2021); however, shark-diving tourism is still inexistent. Despite some opportunistic encounters with angel sharks and smalltooth sand tiger sharks in recreational diving activities, dedicated shark-diving operations were not reported. However, Canarian stakeholders suggest that the Canarian archipelago has a high potential for shark-diving tourism development due to the high abundance of potential shark-diving target species, particularly angel sharks and blue sharks. The first is one of the most commonly encountered specie by recreational scuba divers, mainly in winter season (Gonzáles-Mantilla et al., 2021), and recent research has found that the Canary Islands is the only place in the Northeast Atlantic where angel sharks may be sighted regularly (Barker et al., 2016). Moreover, angel sharks have been recently fully protected by Spanish government, which, according to stakeholders, should be a crucial step prior to shark-diving tourism development.

Blue shark and shortfin mako populations are highly abundant in the Northeast Atlantic (Queiroz et al., 2019) and as migratory species they move through Macaronesian waters being commonly founded in the offshore of the Azores Islands during summer season (Gonzáles-Mantilla et al., 2022) and in the Canary Islands during autumn season. For this reason, Canarian stakeholders suggest it would be possible to develop a shark-diving industry using chumming in offshore waters to lure these pelagic shark species, similar to the Azores. Hammerhead sharks could also be lured using food attraction; however, alike blue and shortfin mako sharks, marine scientists suggest these species would rather prefer feeding with fresh or alive fish similar to Bimini in the Bahamas with Great hammerhead sharks (*Sphyrna mokarran*).

In the last decade diving with female smalltooth sand tiger sharks during summer season in El Hierro has gained popularity. However, this diving experience do not occur every year. Smalltooth sand tiger sharks are a very rare demersal shark species, associated with insular shelves and slopes, with occasional incursions into shallow waters and of poorly known biology and ecology (Barcelos et al., 2018). According to marine scientists, pregnant female individuals overall approach to shallow waters of El Hierro each 2 years, offering an opportunity to dive with them. However, due to the increasing number of divers into this experience, dive operators concomitant with government authorities have developed a code of conduct for managing dive operations. Still, stakeholders suggest further research is needed to avoid detrimental effect on this shark population and potential human risk.

Table 5. Potential target shark species and probability of potential shark-diving sites in the Canary Islands

Island	Dive site	Potential target species	Probability
El Hierro	Mar de Las Calmas Marine Reserve	Smalltooth sand tiger, Hammerhead, Blue and Shortfin mako sharks	Very Likely
	Faro de Orchilla	Hammerhead sharks	Likely
Tenerife	Abades	Angel sharks	Highly Likely
	Teresitas	Angel sharks	Highly Likely
	Gigantes	Angel sharks	Likely
	Galletas	Angel sharks	Very Likely
	Teno-Rasca	Blue, Shortfin mako and Hammerhead sharks	Very Likely
Gran Canaria	Sardina	Angel sharks	Highly Likely
	El cabron	Angel sharks	Very Likely
	Tufia	Angel sharks	Very Likely
	Amadores	Angel sharks	Very Likely
	Mogan	Angel sharks	Very Likely
Fuerteventura	Morro jable/Jandia	Angel sharks	Highly Likely
	Puerto del rosario	Angel sharks	Very Likely
	Lajita	Angel sharks	Very Likely
	Castillo	Angel sharks	Highly Likely
	Cotillo/la concha	Angel sharks	Very Likely
	Lobos Island	Hammerhead sharks	Likely
	Baja de Amanay	Hammerhead sharks	Very Likely
Lanzarote	Playa chica	Angel sharks	Very Likely
	Playa dorada	Angel sharks	Very Likely
	Pechiguera	Angel sharks	Very Likely
La Graciosa	La Graciosa Marine Reserve	Angel sharks	Highly Likely
	Alegranza Island	Blue and Hammerhead sharks	Very Likely

Shark-diving tourism potential in the Canary Islands relies on abundance of shark populations and favorable settings for diving activities which are reflected in a well-established scuba-diving industry in the European market (Gonzáles-Mantilla et al., 2021). Our estimation of shark-diving potential value in the Canarian potential sites showed that 80% of them has at least a Very Likely probability to become a shark-diving site. For example, Teresitas in Tenerife or La Graciosa Marine Reserve in La Graciosa had the same potential value than highly global reckon shark-diving industries such as Ningaloo Reef Marine Park in Australia, or Shark Observatory in Egypt (see Table 3). Although the majority of Canarian dive operators supported the development of a shark-diving industry in this archipelago, a few of them disapproved it arguing potential negative impacts on shark populations (e.g. diving with smalltooth sand tiger sharks in El Hierro). This suggests that there is a need of increasing awareness of potential positive impacts of shark-diving tourism to the local community and potential conservation of shark populations. There is evidence of increasing interest of dive tourists on shark-diving activities in the Canarian archipelago, nonetheless, a further developed research on tourists' perception and willingness to pay for this experience is highly recommended in order to estimate the potential economic impact of this activity.

The Canary Islands is a leading region in European tourism and well-known "sun, sand and sea" tourist destination (Hernández Martín et al., 2021). However, the high expansion of the traditional mass-tourism sector experienced by the islands has led to an increase of the local society's concern about sustainability. Despite its high contribution to local employment and Regional Gross Domestic Product (GDP), tourism sector has not represented a key driver for socioeconomic development of Canarian local community probably due to the dominance and dependence on international operators, lack of diversification and poor support to local entrepreneurs (Lahtinen et al., 2013). Potential new niche markets are clearly required, and shark-diving tourism could be a potential sustainable alternative to integrate into the Canarian marine tourism industry. Given the diversity of species and lack of tourism seasonality, shark-diving activities in the Canary Islands could be undertaken year-round increasing business profitability and local income. This economic contribution could potentially support the creation of Marine Protected Areas around the possible shark-diving sites particularly in those lacking any type of legal protection (66% of potential dive sites). Moreover, the year-round presence of dive operators and tourists at these sites could potentially strengthen protection of these areas, serving as monitors, alarms and deterrents for illegal fisheries activities (Gallagher et al., 2015).

Although a certain level of impact from tourism may always be expected, shark-diving tourism has the potential to provide significant long-term conservation and economic benefits for local communities in many small-islands destinations (e.g. Fiji, Palau, The Bahamas). Our results have shown that the Canary Islands present the attributes needed to potentially become a shark-diving destination. However, this could only be possible if further research on habitat use and movement, ecology, and trophic interactions of shark populations in the Canarian waters, and socioeconomic dimensions are performed. There is also required that dive operators, NGO's, fishermen and government authorities work together in order to ensure that this global emerging industry bring their potential positive benefits in the Canarian archipelago.

5. Conclusions

A new model to identify and assess new potential sites for shark-diving tourism development based on their attributes is proposed. The approach aims to contribute to a better understanding of the attributes required for assessing shark-diving tourism potential on any shark-diving site around the world. Our global analysis of all the existent shark-diving sites has shown the expansion of the global shark-diving industry in the last decade. This analysis could also serve as a global database for future research on shark sciences.

The Canary Islands has shown signs of high potential for shark-diving tourism development; however, our assessment is a first picture of an extensive tourism potential assessment. This study is the first on mapping and contextualizing potential sites for shark-diving tourism development in the Canary Islands and could potentially serve to government authorities as a guide for planning shark-diving tourism development in the archipelago. Future studies on tourist's perception and willingness to pay on potential shark-diving activities in the Canary Islands are needed. Also, considering the potential market of recreational diving activities in the Canarian archipelago, we suggest further research on overall socioeconomic valuation of the Canarian diving industry.

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Conflict of Interest

No potential conflict of interest was reported by the authors.

References

Al Mamun, A., & Mitra, S. (2012). A methodology for assessing tourism potential: Case study Murshidabad District, West Bengal, India. International Journal of Scientific and Research Publications, 2(9), 1-8.

Apps, K., Dimmock, K., Lloyd, D. J., & Huveneers, C. (2017). Is there a place for education and interpretation in shark-based tourism?. Tourism Recreation Research, 42(3), 327-343.

Barcelos, L. M. D., Azevedo, J., Pollerspöck, J., & Barreiros, J. P. (2018). Review of the records of the smalltooth sand tiger shark, Odontaspis ferox (Elasmobranchii: Lamniformes: Odontaspididae), in the Azores. Acta Ichthyologica et Piscatoria, 48(2)), 189-194.

Barker, J., Bartoli, A., Clark, M., Dulvy, N. K., Gordon, C., Hood, A., ... & Meyers, E. (2016). Angelshark action plan for the Canary Islands. ZSL, 2, 3.

Barraclough, A. D., Schultz, L., & Måren, I. E. (2021). Voices of young biosphere stewards on the strengths, weaknesses, and ways forward for 74 UNESCO Biosphere Reserves across 83 countries. Global Environmental Change, 68, 102273.

Catlin, J., Jones, T., & Jones, R. (2012). Balancing commercial and environmental needs: licensing as a means of managing whale shark tourism on Ningaloo reef. Journal of Sustainable Tourism, 20(2), 163-178.

Cisneros-Montemayor, A. M., Barnes-Mauthe, M., Al-Abdulrazzak, D., Navarro-Holm, E., & Sumaila, U. R. (2013). Global economic value of shark ecotourism: implications for conservation. Oryx, 47(3), 381-388.

Cisneros-Montemayor, A. M., Becerril-García, E. E., Berdeja-Zavala, O., & Ayala-Bocos, A. (2020). Shark ecotourism in Mexico: Scientific research, conservation, and contribution to a Blue Economy. In Advances in marine biology (Vol. 85, No. 1, pp. 71-92). Academic Press.

Davidson, L. N., & Dulvy, N. K. (2017). Global marine protected areas to prevent extinctions. Nature ecology & evolution, 1(2), 1-6.

Dulvy, N. K., Simpfendorfer, C. A., Davidson, L. N., Fordham, S. V., Bräutigam, A., Sant, G., & Welch, D. J. (2017). Challenges and priorities in shark and ray conservation. Current Biology, 27(11), R565-R572.

Gallagher, A. J., & Hammerschlag, N. (2011). Global shark currency: the distribution, frequency, and economic value of shark ecotourism. Current Issues in Tourism, 14(8), 797-812.

Gallagher, A.J. and Huveneers, C.P. (2018). Emerging challenges to shark-diving tourism. Marine Policy, 96, pp.9-12.

Gallagher, A. J., Amon, D. J., Bervoets, T., Shipley, O. N., Hammerschlag, N., & Sims, D. W. (2020). The Caribbean needs big marine protected areas. science, 367(6479), 749-749.

Gonzáles-Mantilla, P. G., Gallagher, A. J., León, C. J., & Vianna, G. M. (2021). Challenges and conservation potential of shark-diving tourism in the Macaronesian archipelagos. Marine Policy, 131, 104632.

Gonzáles-Mantilla, P. G., Gallagher, A. J., León, C. J., & Vianna, G. M. (2022). Economic impact and conservation potential of shark-diving tourism in the Azores Islands. Marine Policy, 135, 104869.

Haas, A. R., Fedler, T., & Brooks, E. J. (2017). The contemporary economic value of elasmobranchs in The Bahamas: Reaping the rewards of 25 years of stewardship and conservation. Biological conservation, 207, 55-63.

Healy, T. J., Hill, N. J., Barnett, A., & Chin, A. (2020). A global review of elasmobranch tourism activities, management and risk. Marine Policy, 118, 103964.

Hernández Martín, R., Antonova, N., Celis Sosa, D., Fernández Hernández, C., González Hernández, M., Herrera Priano, F. Á., ... & Simancas Cruz, M. R. (2021). Tourism Observatory of the Canary Islands.

Indab, A. L. (2016). Willingness to pay for whale shark conservation in Sorsogon, Philippines. In Marine and Coastal Ecosystem Valuation, Institutions, and Policy in Southeast Asia (pp. 93-128). Springer, Singapore.

Lahtinen, H., Vilamaa, K., Buligescu, B. & Wintjes, R. (2013). Summary Assessment of the Canary Islands. ESIC European Service Innovation Centre REPORT.

Litman, T. (2003). Accessibility: Defining, evaluating and improving accessibility. Victoria Transport Policy Institute.

Malik, M. I., & Bhat, M. S. (2015). Sustainability of tourism development in Kashmir—Is paradise lost?. Tourism management perspectives, 16, 11-21.

Meyer, L., Barry, C., Araujo, G., Barnett, A., Brunnschweiler, J. M., Chin, A., ... & Huveneers, C. (2021). Redefining provisioning in marine wildlife tourism. Journal of Ecotourism, 1-20.

Mieras, P. A., Harvey-Clark, C., Bear, M., Hodgin, G., & Hodgin, B. (2017). The economy of shark conservation in the Northeast Pacific: the role of ecotourism and citizen science. In Advances in marine biology (Vol. 78, pp. 121-153). Academic Press.

Queiroz, N., Humphries, N. E., Couto, A., Vedor, M., Da Costa, I., Sequeira, A. M., ... & Sousa, L. L. (2019). Global spatial risk assessment of sharks under the footprint of fisheries. Nature, 572(7770), 461-466.

Topelko, K. N., & Dearden, P. (2005). The shark watching industry and its potential contribution to shark conservation. Journal of Ecotourism, 4(2), 108-128.

Vianna, G. M., Meeuwig, J. J., Pannell, D., Sykes, H., & Meekan, M. G. (2011). The socioeconomic value of the shark-diving industry in Fiji. Perth: University of Western Australia. 26p.

Vianna, G. M., Meekan, M. G., Pannell, D. J., Marsh, S. P., & Meeuwig, J. J. (2012). Socio-economic value and community benefits from shark-diving tourism in Palau: a sustainable use of reef shark populations. Biological Conservation, 145(1), 267-277.

Vianna, G. M., Meekan, M. G., Rogers, A. A., Kragt, M. E., Alin, J. M., & Zimmerhackel, J. S. (2018). Shark-diving tourism as a financing mechanism for shark conservation strategies in Malaysia. Marine Policy, 94, 220-226.

Ward-Paige, C. A., Brunnschweiler, J., & Sykes, H. (2020). Tourism-driven ocean science for sustainable use: A case study of sharks in Fiji. bioRxiv.

Yan, L., Gao, B. W., & Zhang, M. (2017). A mathematical model for tourism potential assessment. Tourism Management, 63, 355-365.

Ziegler, J., Dearden, P., & Rollins, R. (2012). But are tourists satisfied? Importance-performance analysis of the whale shark tourism industry on Isla Holbox, Mexico. Tourism Management, 33(3), 692-701.

Ziegler, J., & Dearden, P. (2021). Whale shark tourism as an incentive-based conservation approach. Whale sharks: Biology, ecology, and conservation, 109.

Zimmerhackel, J. S., Kragt, M. E., Rogers, A. A., Ali, K., & Meekan, M. G. (2019). Evidence of increased economic benefits from shark-diving tourism in the Maldives. Marine Policy, 100, 21- 26.

Zimmerhackel, J. S., Rogers, A. A., Meekan, M. G., Ali, K., Pannell, D. J., & Kragt, M. E. (2018). How shark conservation in the Maldives affects demand for dive tourism. Tourism Management, 69, 263-271.

CONCLUSIONS

Scuba-diving tourism is a well-established activity in all the Macaronesian archipelagos; however, shark-diving tourism is still largely undeveloped. Yet, despite the small number of specialized shark-diving operations in Macaronesia, the shark-diving industry has the potential to expand and to become a specialized market in the archipelagos where it is still inexistent. Each of the archipelago in Macaronesia has particular features to develop shark-diving activities, thus, shark-diving tourism industry could potentially serve as a means of transitioning local economies from unsustainable to sustainable non-consumptive uses of marine resources.

The main conclusions of the first chapter are:

Shark-diving tourism is considered a potentially sustainable alternative of non-consumptive use of certain shark species. This industry, which can generate economic benefits for local communities in different parts of the world, could expand in the Macaronesian archipelagos. However, the main target species of today's diving industry are also threatened by commercial and recreational fishing. In particular, pelagic and migratory species populations overlap with Spanish and Portuguese industrial fishing in all Macaronesian waters, while coastal species are being exploited by recreational and artisanal fishing in the Canary Islands and Cape Verde. Although there may be some small operations that can persist locally, developing a strong industry that can provide incentives for local fishermen to support diving activities requires establishing a regional policy to protect sharks. Raising public awareness of the importance of sharks to the health of the oceans and, more importantly, disseminating the ecological and economic benefits of shark-diving operations to local authorities in each archipelago is the first stage of this process. It is also necessary to strengthen the effective management and control of shark catches (and fisheries in general) by local and foreign fleets operating in Macaronesian waters, along with the creation of large-scale protected areas in the region.

Sharks are widely distributed in the world's oceans and, therefore, shark-diving tourism has great potential for expansion. For those places that share regional connectivity, Macaronesia could provide a comparable case study, as there are different levels of industrial development between the archipelagos. However, the recognized potential benefits of shark-diving tourism are not directly applicable to all coastal destinations; therefore, a prior assessment of the potential benefits that may result from the establishment of a shark diving industry in specific locations is essential to achieve sustainable and socio-economic goals.

The main conclusions of the second chapter are:

The economic value of the shark-diving tourism industry targeting pelagic or oceanic species in the Azores Islands and the potential for generating income for conservation of these species were estimated. Despite being one of the most widespread shark groups in the world, the species targeted here, blue shark (*Prionace glauca*) and shortfin mako shark (*Isurus oxyrinchus*), have been modestly represented among shark dive tourism operations. worldwide (more than 10%, Gallagher & Hammerschlag, 2011), and the findings of this research contribute to a better understanding of the possible economic dimensions of this emerging market in the Mid-Atlantic. The contingent valuation analysis based on the willingness to pay survey shows that shark diving tourism from the Azores Islands could help obtain financial resources for the implementation of a marine protected area (MPA) for sharks. However, this industry needs to expand to represent a strong contributor of economic outcomes for the local community and to support sound conservation strategies.

The growth potential of the Azores shark-diving industry relies primarily on attracting more tourists to the region, particularly dedicated shark divers. Greater awareness among local authorities of the economic benefits of this potentially sustainable industry is needed, with the

aim of improving marketing strategies, increasing support for local dive centers to explore this market, and integrating more local workers from the community of the Azores Islands in the shark-diving industry.

The main conclusions of the third chapter are:

A new model is proposed to identify and evaluate new potential sites for the development of shark-diving tourism based on a global analysis of existing diving sites and their common attributes. The approach aims to contribute to a better understanding of the attributes needed to assess the potential for shark-diving tourism at any potential shark-diving site in the world. The global analysis of the existent shark-diving sites has mainly shown the expansion of the global industry in the last decade. In addition, this analysis is also intended to serve as a global database for future shark science research.

The Canary Islands have shown signs of high potential for the development of shark-diving tourism; however, this research is the first image of an extensive evaluation of tourism potential of this industry. This study is the first to map and contextualize potential sites for shark diving tourism development in the Canary Islands and could potentially serve government authorities as a guide for planning shark-diving tourism development in the archipelago.

The present work contributes to fill an academic gap on shark diving tourism, and on sharks in general, in the Macaronesian region, contextualizing and describing their potential attributes for the development of this industry, analyzing the potential economic impact for local communities, as well as the potential conservation benefits for certain species. However, this research has limitations mainly due to the scarce previous information on shark populations in biological and ecological terms, and their consumptive use in Macaronesia (e.g.: the historical data of shark fishing in the Canary Islands). In addition, the present investigation could not address a study of the potential of diving with sharks that included primary data offered by tourists in the Canary Islands and Cape Verde, mainly due to the restrictions caused by the COVID-19 pandemic between the years 2020-2021.

Another aspect that could be considered a limitation is the representative sample of spending by diving tourists in the Azores Islands. Although the surveys were carried out between the end of August and the beginning of October 2019, the Azorean shark diving season began at the end of June. For logistical reasons, the operations ended at the end of September due to the arrival of Hurricane Lorenzo, for which the sample of tourists surveyed represented one third of the total season.

Finally, in the research conducted in the Canary Islands, it was initially planned to interview representatives of local fishermen's associations, also known as "Cofradías", with the aim of obtaining first-hand information on shark fishing in the Canary archipelago. However, for logistical reasons, it was not possible to contact these actors who could have provided important information for this work, as has been observed in other investigations (Jabado et al., 2015; García-Rodríguez & Sosa-Nishizaki, 2020; Mason et al., 2020; Almojil, 2021).

This research, despite its limitations, has met the initially proposed objectives, however, it should be considered as the starting point for future research on the study of sharks in the Macaronesian region. First of all, it is recommended to conduct further research on the long-term benefit potential of shark-diving activities in their archipelagos. To achieve this, the most important knowledge gaps that need to be filled are data on the abundance and distribution of shark populations in Macaronesian waters, socio-economic assessments of the potential shark-diving industry in each archipelago, up-to-date data on shark fisheries from the Northeast

Atlantic to the Eastern Central Atlantic Ocean, and assessments of local community perceptions (e.g.: fishermen) and social inclusion in shark-diving tourism industry.

An assessment of the potential for shark diving in Madeira is also recommended. Although it was not taken into account in the analysis conducted in the first chapter since local diving operators did not report encounters with sharks, the data obtained in the bibliographic review consider that there is an abundance of target species for tourism in their territory. Regarding the Canary Islands and Cape Verde, future studies are needed on the perception and willingness to pay of tourists for potential dedicated diving activities with sharks. Furthermore, considering the potential market for recreational diving activities in both archipelagos, further research on the overall socioeconomic valuation of their diving industry is highly suggested.

References

Almojil, D. (2021). Local ecological knowledge of fisheries charts decline of sharks in data-poor regions. Marine Policy, 132, 104638.

Gallagher, A. J., & Hammerschlag, N. (2011). Global shark currency: the distribution, frequency, and economic value of shark ecotourism. Current Issues in Tourism, 14(8), 797-812.

García-Rodríguez, E., & Sosa-Nishizaki, O. (2020). Artisanal fishing activities and their documented interactions with juvenile white sharks inside a nursery area. Aquatic Conservation: Marine and Freshwater Ecosystems, 30(5), 903-914.

Jabado, R. W., Al Ghais, S. M., Hamza, W., & Henderson, A. C. (2015). The shark fishery in the United Arab Emirates: an interview based approach to assess the status of sharks. Aquatic Conservation: Marine and Freshwater Ecosystems, 25(6), 800-816.

Mason, J. G., Alfaro-Shigueto, J., Mangel, J. C., Crowder, L. B., & Ardoin, N. M. (2020). Fishers' solutions for hammerhead shark conservation in Peru. Biological Conservation, 243, 108460.

SUPPLEMENTARY MATERIAL

SM.1. Chapter 1

List of shark species most frequently observed in the Macaronesian archipelagos.

Macaronesian archipelagos	Shark species	Source
Azores	Tope shark (*Galeorhinus galeus*), gulper shark (*Centrophorus granulosus*), blue shark (*Prionace glauca*), short fin mako (*Isurus oxyrinchus*), smooth hammerhead (*Sphyrna zygaena*), sharpnose sevengill shark (*Heptranchias perlo*), whale shark (*Rhincodon typus*), bigeye thresher (*Alopias superciliosus*) and kitefin shark (*Dalatias licha*).	Barreiros and Gadig (2011); Carneiro et al. (2014).
Madeira	Leafscale gulper shark (*Centrophorus squamosus*), blue shark (*Prionace glauca*), tope shark (*Galeorhinus galeus*), whale shark (*Rhincodon typus*), sharpnose sevengill shark (*Heptranchias perlo*), bigeye thresher (*Alopias superciliosus*), rough longnose dogfish (*Deania hystricosa*), and common smooth-hound (*Mustelus mustelus*).	Carneiro et al. (2014); Biscoito et al. (2018)
Canary Islands	Angel shark (*Squatina squatina*), short fin mako (*Isurus oxyrinchus*), blue shark (*Prionace glauca*), whale shark (*Rhincodon typus*), smooth hammerhead (*Sphyrna zygaena*) and common smoothhound (*Mustelus mustelus*).	De la Cruz Modino, (2011)
Cape Verde	Common smoothhound (*Mustelus mustelus*), atlantic weasel shark (*Paragaleus pectoralis*), sharpnose sevengill shark (*Heptranchias perlo*), milk shark (*Rhizoprionodon acutus*), smooth hammerhead (*Sphyrna zygaena*), spiny dogfish (*Squalus acanthias*), spinner shark (*Carcharhinus brevipinna*), oceanic whitetip shark (*Carcharhinus longimanus*), blacktip shark (*Carcharhinus limbatus*), tiger shark (*Galeocerdo cuvier*), nurse shark (*Ginglymostoma cirratum*), dusky shark (*Carcharhinus obscurus*), lemon shark (*Negaprion brevirostris*), Galapagos shark (*Carcharhinus galapagensis*), whale shark (*Rhincodon typus*) and sand tiger shark (*Carcharias taurus*).	Diop and Dossa (2011), Wirtz et al., 2013).

Published shark-related studies in terms of fisheries, tourism and conservation in the Macaronesian archipelagos from 2003 up until and including 2019 (A: Article; TR: Technical report; C: Chapter; CP: Conference paper; PT: Published thesis and B: Book).

No.	References	Type	Macaronesia	Azores Islands	Madeira	Canary Islands	Cape Verde	Fisheries	Shark-diving tourism	Conservation
1	Correia and Smith (2003)	A		X	X			X		
2	Stobberup et al. (2004)	A					X	X		
3	Perrota (2004)	A		X				X		
4	Hareide et al. (2007)	TR	X					X		
5	Oceana (2007)	TR	X					X		
6	Aires-da-Silva and Gallucci (2007)	A		X						X
7	Aires-da-Silva et al. (2008)	C		X				X		
8	Oceana (2009)	TR	X					X		
9	Benchimol et al. (2009)	CP					X			X
10	De la Cruz Modino et al. (2010)	B				X			X	
11	Fowler and Séret (2010)	TR	X					X		X
12	Diop and Dossa (2011)	B					X			
13	Barreiros and Gadig (2011)	B		X				X		X
14	Calado et al. (2011)	C		X					X	
15	Carvalho et al. (2011)	A		X				X		
16	Saavedra (2011)	PT				X		X		
17	De la Cruz Modino (2011)	A				X			X	
18	Carneiro (2012)	A					X	X		
19	Morato (2011)	TR		X	X			X		
20	Narvaez (2013)	PT				X				X
21	Ressurreição and Giacomello (2013)	A		X				X	X	X
22	Bentz et al. (2013)	A		X					X	X
23	Pham et al. (2013)	A		X				X		
24	Barreiros et al. (2014)	A		X					X	
25	Vandeperre et al. (2014)	A		X	X					X
26	Bentz et al. (2014)	A		X					X	
27	Afonso et al. (2014)	C		X						X
28	Couce-Montero et al. (2015)	A				X		X		
29	Castro et al. (2015)	A				X		X		
30	Ojamaa (2015)	TR		X				X		
31	Goulding and Stobberup (2015)	TR	X					X		
32	EU Comission (2016)	TR	x							x
33	Golding and Lda, M. (2016)	TR	X					X		
34	Fontes et al. (2016)	CP		X				X		
35	Correia et al. (2016)	A		X	X			X		
36	Torres et al. (2016)	A		X				X		
37	Tavares (2016)	PT		X					X	
38	Barker et al. (2016)	TR				X				X
39	Oliveira (2016)	PT		X					X	X
40	Lopes et al. (2016)	A					X	X		
41	EU Commission (2017)	TR	X						X	
42	Das and Afonso (2017)	A		X						X
43	Meyers et al. (2017)	A				X				X
44	Torres et al. (2017)	A		X					X	
45	Torres (2017)	PT		X					X	X
46	Coelho et al. (2017)	TR	X					X		X
47	Ponte et al. (2018)	A		X					X	

No.	References	Type	Macaronesia	Azores Islands	Madeira	Canary Islands	Cape Verde	Fisheries	Shark-diving tourism	Conservation
48	ICES (2018)	TR	X					X		
49	Freitas et al., (2018)	A				X		X		
50	Duran et al. (2018)	A				X		X		
51	Fauconnet et al. (2019)	A		X				X		
52	Queiroz et al. (2019)	A	X					X		X
53	Couce-Montero et al. (2019)	TR	X					X		

SM. 2. Chapter 2

Formulas to calculate the economic value and distribution of revenues from shark-diving in the Azores Islands.

Abbreviation	Estimate	Formula	Source
Business revenues from shark-diving tourism			
BROSD	Business revenues from opportunist shark divers	SDED x A x SDT x (1-DSDF)	Dive operator questionnaire and tourist questionnaire
BRDSD	Business revenues from dedicated shark divers	SDET x SDT x DSDF	Dive operator questionnaire and tourist questionnaire
Local community benefits from shark-diving			
DCID	Direct community income from diving	W x E	Dive operator questionnaire
DCISD	Direct community income from shark-diving	W x E x SDF	Dive operator questionnaire
Tax revenues from shark-diving			
BRTOSD	Business revenues tax from opportunist shark divers	BROSD x BT	Dive operator questionnaire
BRTDSD	Business revenue tax from dedicated shark divers	BRDSD x BT	Dive operator questionnaire
Expenditures			
SDET	Shark divers expenditure per trip	Food and drinks + Accommodation + Diving expenses + Tourism activities + Domestic transportmation + Extra expenses	Tourist questionnaire
SDED	Shark divers expenditure per day	SDET/T	Tourist questionnaire
Divers' willingness to pay			
REV	Potential annual revenues from extra fee for MPA for sharks and increase on shark-diving trip	WTP^{ENF} x SDT x A	Tourist questionnaire

SM. 3. Chapter 3

Industry	Dive site	Legal protection	Method	Species	Activity	Seasonality	Diver level	Abundance	Accessibility	Visibility	Fishing area
Australia	Ningaloo Reef Marine Park, Western Australia	Yes	Natural aggregation	Whale sharks (*Rhincodon typus*)	Snorkeling	From March to July	None required	High	High	Intermediate	Eastern Indian Ocean
Australia	Osprey Reef, Coral Sea Marine Park, Queensland	Yes	Provisioning	Grey reef sharks (*Carcharhinus amblyrhynchos*), whitetip reef sharks (*Triaenodon obesus*), silvertip sharks (*Carcharhinus albimarginatu*), scalloped hammerhead (*Sphyrna lewini*) and great hammerhead sharks (*Sphyrna mokarran*)	Scuba	Year round	Intermediate	High	Low (Only via liveaboard)	Intermediate	Western Central Pacific
Australia	Wolf Rock Marine Sanctuary, Queensland	Yes	Natural aggregation	Grey nurse sharks (*Carcharias taurus*), leopard sharks (*Stegostoma Fasciatum*)	Scuba	Year round	Intermediate	High	High	Intermediate	Western Central Pacific
Australia	Julian Rocks, Cape Byron Marine Park, New South Wales	No	Natural aggregation	Grey nurse sharks (*Carcharias taurus*), leopard sharks (*Stegostoma Fasciatum*)	Scuba	Year round	Basic	High	High	Intermediate	Western Central Pacific
Australia	Fish Rock, New South Wales	No	Natural aggregation	Grey nurse sharks (*Carcharias taurus*)	Scuba	Year round	Basic	High	Intermediate	Intermediate	Southwest Pacific
Australia	Magic Point, New South Wales	No	Natural aggregation	Grey nurse sharks (*Carcharias taurus*)	Scuba	Year round	Advanced	High	High	Intermediate	Southwest Pacific
Australia	Neptune Islands Conservation Park, South Australia	Yes	Provisioning	White sharks (*Carcharodon carcharias*)	Cage diving	Year round	None required	Intermediate	Intermediate	Intermediate	Eastern Indian Ocean
Belize	Shark Ray Alley, Hol Chan Marine Reserve, Ambergris Caye	Yes	Provisioning	Nurse sharks (*Ginglymostoma cirratum*)	Snorkeling	Year round	None required	High	High	Intermediate	Western Central Atlantic
Belize	Gladden Split and Silk Cayes Marine Reserve, Placencia	Yes	Natural aggregation	Whale sharks (*Rhincodon typus*)	Scuba and snorkeling	From March to June	Basic	High	Intermediate	Intermediate	Western Central Atlantic

Industry	Dive site	Legal protection	Method	Species	Activity	Seasonality	Diver level	Abundance	Accessibility	Visibility	Fishing area
Canada	Flora Inlet, Hornby Island, Helliwell Provincial Park	Yes	Natural aggregation	Bluntnose sixgill sharks (*Hexanchus griseus*)	Scuba	From April to September	Basic	Intermediate	High	Intermediate	Northeast Pacific
Colombia	Malpelo Fauna and Flora Marine Sanctuary, Malpelo Island	Yes	Natural aggregation	Scalloped Hammerhead sharks (*Sphyrna lewini*), silky sharks (*Carcharhinus falciformis*), whale sharks (*Rhincodon typus*) and smalltooth sand tiger shark (*Odontaspis ferox*)	Scuba	Year round	Basic	High	Low (Only via liveaboard)	Intermediate	Southeast Pacific
Colombia	Providencia, Sea Flower Marine Protected Area	Yes	Provisioning	Caribbean reef sharks (*Carcharhinus perezi*), Blacktip sharks (*Carcharhinus limbatus*)	Scuba	Year round	Basic	High	High	High	Western Central Atlantic
Costa Rica	Cocos Island National Park	Yes	Natural aggregation	Scalloped Hammerhead sharks (*Sphyrna lewini*), Whitetip reef shark (*Triaenodon obesus*), whale sharks (*Rhincodon typus*)	Scuba	Year round	Basic	High	Low (Only via liveaboard)	High	Eastern Central Pacific
Costa Rica	Big Scare, Bat Islands, Santa Rosa National Park	Yes	Natural aggregation	Bull sharks (*Carcharhinus leucas*)	Scuba	From May to November	Advanced	Intermediate	Intermediate	High	Eastern Central Pacific
Cuba	Gardens of the Queen Marine Park	Yes	Natural aggregation	Caribbean reef sharks (*Carcharhinus perezi*), silky sharks (*Carcharhinus falciformis*), nurse sharks (*Ginglymostoma cirratum*), lemon sharks (*Negaprion brevirostris*), blacktip sharks (*Carcharhinus limbatus*), great hammerhead (*Sphyrna mokarran*) and Whale sharks (*Rhincodon typus*)	Scuba	Year round	Basic	High	Low (Only via liveaboard)	High	Western Central Atlantic
Ecuador	Darwin's arch, Galapagos Marine Reserve	Yes	Natural aggregation	Scalloped Hammerhead sharks (*Sphyrna lewini*), Whale sharks (*Rhincodon typus*), Silky sharks (*Carcharhinus falciformis*), blacktip sharks (*Carcharhinus limbatus*) and Galapagos sharks (*Carcharhinus galapagensis*)	Scuba	Year round	Basic	High	Low (Only via liveaboard)	Intermediate	Southeast Pacific

Industry	Dive site	Legal protection	Method	Species	Activity	Seasonality	Diver level	Abundance	Accessibility	Visibility	Fishing area
Ecuador	Shark point, Galapagos Marine Reserve	Yes	Natural aggregation	Whale sharks (*Rhincodon typus*), Scalloped Hammerhead sharks (*Sphyrna lewini*) and Galapagos sharks (*Carcharhinus galapagensis*)	Scuba	Year round	Advanced	High	Low (Only via liveaboard)	Intermediate	Southeast Pacific
Ecuador	Gordon Rocks, Galapagos Marine Reserve	Yes	Natural aggregation	Scalloped Hammerhead sharks (*Sphyrna lewini*), Galapagos sharks (*Carcharhinus galapagensis*)	Scuba	Year round	Intermediate/ advanced	High	High	Intermediate	Southeast Pacific
Ecuador	Roca Redonda, Galapagos Marine Reserve	Yes	Natural aggregation	Scalloped Hammerhead sharks (*Sphyrna lewini*), Galapagos sharks (*Carcharhinus galapagensis*), Silky sharks (*Carcharhinus falciformis*)	Scuba	Year round	Advanced	High	Intermediate	Intermediate	Southeast Pacific
Egypt	Jackson reef, Tiran Straits, Ras Mohammed National Park	Yes	Natural aggregation	Scalloped Hammerhead sharks (*Sphyrna lewini*), Whitetip reef sharks (*Triaenodon obesus*), Grey reef sharks (*Carcharhinus amblyrhynchos*)	Scuba	From July to September	Intermediate	High	High	High	Western Indian Ocean
Egypt	Shark & Yolanda Reef, Ras Mohammed National Park	Yes	Natural aggregation	Whitetip reef sharks (*Triaenodon obesus*), Grey reef sharks (*Carcharhinus amblyrhynchos*) and blacktip reef shark (*Carcharhinus melanopterus*)	Scuba	From July to September	Intermediate	High	High	High	Western Indian Ocean
Egypt	Shark Observatory, Ras Mohammed National Park	Yes	Natural aggregation	Whitetip reef sharks (*Triaenodon obesus*), Grey reef sharks (*Carcharhinus amblyrhynchos*) blacktip reef shark (*Carcharhinus melanopterus*), whale sharks (*Rhincodon typus*)	Scuba	From July to September	Advanced	High	High	High	Western Indian Ocean

Industry	Dive site	Legal protection	Method	Species	Activity	Seasonality	Diver level	Abundance	Accessibility	Visibility	Fishing area
Egypt	Elphinstone reef, Marsa Alam	No	Natural aggregation	Oceanic whitetip shark (*Carcharhinus longimanus*), Scalloped Hammerhead sharks (*Sphyrna lewini*)	Scuba	From October to December (oceanic whitetip shark). From July to September (Hammerhead sharks)	Advanced	Intermediate	High	High	Western Indian Ocean
England	Cornwall	No	Provisioning and Natural aggregation	Blue sharks (*Prionace glauca*) and basking sharks (*Cetorhinus maximus*)	Snorkeling	From June to October	None required	Intermediate	Intermediate	Low	Northeast Atlantic
England	Plymouth, Devon	No	Provisioning	Blue sharks (*Prionace glauca*)	Snorkeling	From June to October	None required	Intermediate	Intermediate	Low	Northeast Atlantic
Fiji	Shark Reef Marine Reserve, Beqa Lagoon, Viti Levu	Yes	Provisioning	Bull sharks (*Carcharhinus leucas*), tawny nurse sharks (*Nebrius ferrugineus*), Whitetip reef sharks (*Triaenodon obesus*), Grey reef sharks (*Carcharhinus amblyrhynchos*) blacktip reef shark (*Carcharhinus melanopterus*), sicklefin lemon sharks (*Negaprion acutidens*)	Scuba	Year round	Intermediate	High	High	High	Western Central Pacific
Fiji	Barefoot Kuata, Yasawa Islands	No	Provisioning and natural aggregation	Bull sharks (*Carcharhinus leucas*) and whitetip reef sharks (*Triaenodon obesus*)	Scuba and snorkeling	Year round	None required	High	High	High	Western Central Pacific
Fiji	Namena Marine Reserve, Savusavu	Yes	Natural aggregation	Whitetip reef sharks (*Triaenodon obesus*), Grey reef sharks (*Carcharhinus amblyrhynchos*)	Scuba and snorkeling	Year round	None required	High	Intermediate	High	Western Central Pacific

Industry	Dive site	Legal protection	Method	Species	Activity	Seasonality	Diver level	Abundance	Accessibility	Visibility	Fishing area
Fiji	Somosomo Strait, Vanua Levu	No	Natural aggregation	Tawny nurse sharks (*Nebrius ferrugineus*), Whitetip reef sharks (*Triaenodon obesus*), Grey reef sharks (*Carcharhinus amblyrhynchos*), blacktip reef shark (*Carcharhinus melanopteru*), leopard sharks (*Stegostoma Fasciatum*)	Scuba	Year round	Intermediate	High	High	High	Western Central Pacific
Fiji	Shark Alley and Solo Reef, The Great Astrolabe Reef, Kadavu	No	Natural aggregation	Grey reef sharks (*Carcharhinus amblyrhynchos*), Bull sharks (*Carcharhinus leucas*)	Scuba	Year round	Basic	High	High	High	Western Central Pacific
French Polynesia	Tiputa Pass, Rangiroa	No	Natural aggregation	Great hammerhead sharks (*Sphyrna mokarran*), grey reef sharks (*Carcharhinus amblyrhynchos*)	Scuba and snorkeling	Year round	Basic/ Intermediate	High	High	High	Western Central Pacific
French Polynesia	Avatoru Pass, Rangiroa	No	Natural aggregation and provisioning	Silvertip sharks (*Carcharhinus albimarginatus*), grey reef sharks (*Carcharhinus amblyrhynchos*)	Scuba	Year round	Basic	High	High	High	Western Central Pacific
French Polynesia	Tumakohua Pass, South Fakarava, Fakarava Biosphere reserve	No	Natural aggregation	Grey reef sharks (*Carcharhinus amblyrhynchos*), blacktip reef sharks (*Carcharhinus melanopteru*)	Scuba and snorkeling	Year round	Basic	High	High	High	Western Central Pacific
French Polynesia	Tiki Point and Opunohu Canyons, Moorea Reef	No	Natural aggregation and provisioning	Sicklefin Lemon sharks (*Negaprion acutidens*), blacktip reef sharks (*Carcharhinus melanopteru*), grey reef sharks (*Carcharhinus amblyrhynchos*)	Scuba and snorkeling	Year round	Basic	High	High	High	Western Central Pacific
Honduras	Cara cara, Roatan Marine Park, Bay Islands	Yes	Provisioning	Caribbean Reef Sharks (*Carcharhinus perezi*)	Scuba	Year round	Advanced	High	High	Intermediate	Western Central Atlantic

Industry	Dive site	Legal protection	Method	Species	Activity	Seasonality	Diver level	Abundance	Accessibility	Visibility	Fishing area
Honduras	Utila, Bay Islands	Yes	Natural aggregation	Whale sharks (*Rhincodon typus*)	Snorkeling	From March to May and from August to October	None required	Intermediate	High	Intermediate	Western Central Atlantic
Indonesia	Cenderawasih Bay Marine Park, West Papua	Yes	Natural aggregation	Whale Sharks (*Rhincodon typus*)	Scuba and snorkeling	From June to October	Basic	Intermediate	Low (Only via liveaboard)	Intermediate	Western Central Pacific
Indonesia	Derawan, Sangalaki, Kakaban and Maratua, Derawan Islands	Yes	Natural aggregation	Grey reef sharks (*Carcharhinus amblyrhynchos*), leopard sharks (*Stegostoma Fasciatum*), whitetip reef sharks (*Triaenodon obesus*), scalloped hammerhead sharks (*Sphyrna lewini*), thresher sharks (*Alopias pelagicus*) and whale sharks (*Rhincodon typus*)	Scuba	Year round	Basic/ Intermediate	High	High	Intermediate	Western Central Pacific
Indonesia	Kaimana Marine Protected Area, Triton Bay, West Papua	Yes	Natural aggregation	Whale sharks (*Rhincodon typus*), Indonesian wobbegong shark (*Orectolobus leptolineatus*), walking sharks (*Hemiscyllium Halmahera*)	Scuba	From October to December	Basic/ Intermediate	Intermediate	Intermediate	Intermediate	Western Central Pacific
Isle of Man	Niarbyl Fisheries Restricted Area	Yes	Natural aggregation	Basking sharks (*Cetorhinus maximus*)	Scuba and snorkeling	From June to August	None required	Intermediate	High	Intermediate	Northeast Atlantic
Israel	Nahal Hadera Park, Hadera	Yes	Natural aggregation	Dusky sharks (*Carcharhinus obscurus*) and Sandbar sharks (*Carcharhinus plumbeus*)	Scuba	From November to March	Basic/ Intermediate	High	High	Low	Mediterranean and Black Sea
Japan	Okimae-ne, Ito, Chiba	No	Provisioning	Banded houndsharks (*Triakis scyllium*)	Scuba	Year round	Intermediate	High	High	Intermediate	Northwest Pacific
Japan	Yonaguni Island	No	Natural aggregation	Scalloped hammerhead sharks (*Sphyrna lewini*)	Scuba	From January to March	Advanced	High	High	High	Northwest Pacific

Industry	Dive site	Legal protection	Method	Species	Activity	Seasonality	Diver level	Abundance	Accessibility	Visibility	Fishing area
Japan	Hatsushima Island	No	Natural aggregation	Japanese bullhead sharks (*Heterodontus japonicus*), Japanese angelsharks (*Squatina japonica*)	Scuba	From December to February	Basic	High	High	Intermediate	Northwest Pacific
Japan	Mikomoto Island	No	Natural aggregation	Scalloped hammerheads sharks (*Sphyrna lewini*), Japanese wobbegong sharks (*Orectolobus japonicas*)	Scuba	From July to October (Scalloped hammerhead sharks). From December to February (Japanese wobbegong sharks)	Intermediate	High	High	Intermediate	Northwest Pacific
Kenya	Watamu Marine National Park	Yes	Natural aggregation	Whale sharks (*Rhincodon typus*)	Scuba	From October to February	Basic	Intermediate	High	Intermediate	Western Indian Ocean
Kenya	Shark Point, Mombasa Marine Park	Yes	Natural aggregation	Whitetip reef shark (*Triaenodon obesus*)	Scuba	Year round	Basic	High	High	Low	Western Indian Ocean
Lebanon	Shark Point, Beirut	No	Natural aggregation	Smalltooth Sand Tiger (*Odontaspis ferox*) and the Grey Nurse sharks (*Carcharias taurus*)	Scuba	From July to October	Advanced	Intermediate	High	Intermediate	Mediterranean and Black Sea

Industry	Dive site	Legal protection	Method	Species	Activity	Seasonality	Diver level	Abundance	Accessibility	Visibility	Fishing area
Madagascar	Rosario, Nosy Be	No	Natural aggregation	Whale sharks (*Rhincodon typus*)	Snorkeling	From September to December	None required	Intermediate	High	High	Western Indian Ocean
Madagascar	Shark Point, Nosy Be	No	Natural aggregation	Whitetip reef sharks (*Triaenodon obesus*), Grey reef sharks (*Carcharhinus amblyrhynchos*)	Scuba	Year round	Advanced	Intermediate	High	High	Western Indian Ocean
Malaysia	Layang Layang Atoll, Sabah	No	Natural aggregation	Scalloped hammerhead sharks (*Sphyrna lewini*)	Scuba	From March to June	Intermediate/ Advanced	High	High	High	Western Central Pacific
Malaysia	Sipadan Island Park, Sabah	Yes	Natural aggregation	Whitetip reef (*Triaenodon obesus*), grey reef sharks (*Carcharhinus amblyrhynchos*) and scalloped hammerhead sharks (*Sphyrna lewini*)	Scuba	Year round	Basic	High	High	High	Western Central Pacific
Maldives	Fuvahmulah Atoll	No	Natural aggregation	Tiger sharks (*Galeocerdo cuvier*), thresher sharks (*Alopias pelagicus*), Whitetip reef (*Triaenodon obesus*), grey reef sharks (*Carcharhinus amblyrhynchos*), silvertip sharks (*Carcharhinus albimarginatus*), Scalloped hammerheads sharks (*Sphyrna lewini*), great hammerhead sharks (*Sphyrna mokarran*) and whale sharks (*Rhincodon typus*)	Scuba	Year round	Advanced	High	High	High	Western Indian Ocean
Maldives	Fotteyo Kandu, Vaavu Atoll	No	Natural aggregation	Scalloped hammerheads sharks (*Sphyrna lewini*), great hammerhead sharks (*Sphyrna mokarran*), whitetip reef (*Triaenodon obesus*), grey reef sharks (*Carcharhinus amblyrhynchos*)	Scuba	Year round	Advanced	Intermediate	Intermediate	Intermediate	Western Indian Ocean

Industry	Dive site	Legal protection	Method	Species	Activity	Seasonality	Diver level	Abundance	Accessibility	Visibility	Fishing area
Maldives	Alimatha Faru, Vaavu atoll	No	Natural aggregation and provisioning	Tawny nurse shark (*Nebrius ferrugineus*)	Scuba and snorkeling	Year round	Basic	High	Intermediate	Intermediate	Western Indian Ocean
Maldives	Miyaru Kandu Marine Reserve, Vaavu Atoll	Yes	Natural aggregation	Whitetip reef (*Triaenodon obesus*), grey reef sharks (*Carcharhinus amblyrhynchos*), silvertip sharks (*Carcharhinus albimarginatus*), blacktip reef sharks (*Carcharhinus melanopteru*)	Scuba	Year round	Intermediate	High	Intermediate	Intermediate	Western Indian Ocean
Maldives	South Ari Atoll Marine Protected Area	Yes	Natural aggregation	Whale sharks (*Rhincodon typus*)	Snorkeling	Year round	None required	Intermediate	High	High	Western Indian Ocean
Maldives	Hammerhead Shark Point, Rasdhoo Madivaru	Yes	Natural aggregation	Scalloped hammerhead sharks (*Sphyrna lewini*)	Scuba	From December to April	Advanced	High	High	Intermediate	Western Indian Ocean
Mauritius	The Pass of Jacque, South West	No	Natural aggregation	Grey reef sharks (*Carcharhinus amblyrhynchos*), bull sharks (*Carcharhinus leucas*)	Scuba	Year round	Advanced	High	High	Intermediate	Western Indian Ocean
Mauritius	Passage of Belle Mare, East Coast	No	Natural aggregation	Grey reef sharks (*Carcharhinus amblyrhynchos*), bull sharks (*Carcharhinus leucas*)	Scuba	Year round	Intermediate/ Advanced	High	High	Intermediate	Western Indian Ocean
Mauritius	Sharks Pit, Flat Island	No	Natural aggregation	Grey reef sharks (*Carcharhinus amblyrhynchos*), bull sharks (*Carcharhinus leucas*), silvertip sharks (*Carcharhinus albimarginatus*), blacktip reef sharks (*Carcharhinus melanopteru*)	Scuba	Year round	Advanced	High	High	High	Western Indian Ocean
Mexico	Holbox, Reserva Natural Yum Balam, Quintana Roo	Yes	Natural aggregation	Whale sharks (*Rhincodon typus*)	Snorkeling	From May to September	None required	High	High	Intermediate	Western Central Atlantic

Industry	Dive site	Legal protection	Method	Species	Activity	Seasonality	Diver level	Abundance	Accessibility	Visibility	Fishing area
Mexico	Guadalupe Island Biosphere Reserve	Yes	Natural aggregation	White shark (*Carcharodon carcharias*)	Cage diving	From August to October	None required/ Basic	Intermediate	Low (only via liveaboard)	High	Eastern Central Pacific
Mexico	Socorro Marine National Park, The Revillagigedo Archipelago	Yes	Natural aggregation	Whale sharks (*Rhincodon typus*), scalloped hammerhead sharks (*Sphyrna lewini*)	Scuba	From November to May	Advanced	High	Low (only via liveaboard)	High	Eastern Central Pacific
Mexico	Playa del Carmen, Quintana Roo	No	Provisioning	Bull sharks (*Carcharhinus leucas*)	Scuba	From November to March	Basic	Intermediate	High	High	Western Central Atlantic
Mexico	Cabo Pulmo National Park, Gulf of California	Yes	Natural aggregation	Bull sharks (*Carcharhinus leucas*)	Scuba	From December to August	Basic	Intermediate	High	Intermediate	Eastern Central Pacific
Mexico	Bahia de Los Angeles Biosphere Reserve, Baja California	No	Natural aggregation	Whale sharks (*Rhincodon typus*)	Snorkeling	From June to December	None required	Intermediate	High	Intermediate	Eastern Central Pacific
Mexico	El Bajo Espíritu Santo, Zona Marina del Archipiélago de Espíritu Santo National Park, Baja California Sur	Yes	Natural aggregation	Scalloped hammerhead shark (*Sphyrna lewini*)	Scuba	From October to February	Advanced	Intermediate	High	Intermediate	Eastern Central Pacific
Mexico	La Paz Bay, Baja California Sur	No	Natural aggregation	Whale sharks (*Rhincodon typus*)	Snorkeling	From October to May	None required	Intermediate	High	High	Eastern Central Pacific
Mexico	Cabo San Lucas, Baja California Sur	No	Natural aggregation and provisioning	Silky shark (*Carcharhinus falciformis*), Blue sharks (*Prionace glauca*), Smooth hammerhead sharks (*Sphyrna zygaena*) and Shortfin mako shark (*Isurus oxyrinchus*)	Scuba and snorkeling	Year round	Basic	High	High	Intermediate	Eastern Central Pacific

Industry	Dive site	Legal protection	Method	Species	Activity	Seasonality	Diver level	Abundance	Accessibility	Visibility	Fishing area
Mexico	Islas Marias Biosphere Reserve, San Blas, Riviera Nayarit	No	Natural aggregation	Whale sharks (*Rhincodon typus*)	Snorkeling	From May to September	None required	Intermediate	High	Intermediate	Eastern Central Pacific
Mexico	Cancun, Quintana Roo	No	Provisioning	Shortfin mako shark (*Isurus oxyrinchus*), Longfin mako shark (*Isurus paucus*)	Cage diving	Year round	None required	Intermediate	High	High	Western Central Atlantic
Mozambique	Praia do Tofo	No	Natural aggregation	Whale sharks (*Rhincodon typus*)	Snorkeling	From September to February	None required	Intermediate	High	Intermediate	Western Indian Ocean
Mozambique	Bazaruto Archipelago National Park	Yes	Natural aggregation	Whale sharks (*Rhincodon typus*)	Snorkeling	From October to April	None required	Intermediate	High	Intermediate	Western Indian Ocean
Mozambique	Pinnacles reef, Ponta do Ouro Partial Marine Reserve	Yes	Natural aggregation	Bull sharks (*Carcharhinus leucas*), tiger sharks (*Galeocerdo cuvier*), scalloped hammerhead sharks (*Sphyrna lewini*), grey reef sharks (*Carcharhinus amblyrhynchos*), leopard sharks (*Stegostoma Fasciatum*), whitetip reef sharks (*Triaenodon obesus*), blacktip reef shark (*Carcharhinus melanopterus*)	Scuba	From September to April	Advanced	High	High	Intermediate	Western Indian Ocean
Netherland Antilles	Big Mama's Reef, Saint Martin Nature Reserve	Yes	Provisioning	Caribbean reef sharks (*Carcharhinus perezi*)	Scuba	Year round	Basic	Intermediate	High	High	Western Central Atlantic
Papua New Guinea	Fathers Reefs, Tufi	No	Natural aggregation and Provisioning	Whitetip reef sharks (*Triaenodon obesus*), grey reef sharks (*Carcharhinus amblyrhynchos*), silvertip sharks (*Carcharhinus albimarginatus*)	Scuba	Year round	Basic/ Intermediate	High	High	Intermediate	Western Central Pacific
Philippines	Monad Shoal Marine Reserve, Malapascua Island	Yes	Natural aggregation	Thresher sharks (*Alopias pelagicus*)	Scuba	Year round	Intermediate	Intermediate	High	Intermediate	Western Central Pacific

Industry	Dive site	Legal protection	Method	Species	Activity	Seasonality	Diver level	Abundance	Accessibility	Visibility	Fishing area
Philippines	Gato Island Marine Reserve	Yes	Natural aggregation	Whitetip reef sharks (*Triaenodon obesus*)	Scuba	Year round	Basic	Intermediate	High	Intermediate	Western Central Pacific
Philippines	Kemod Shoal	No	Natural aggregation	Scalloped hammerhead sharks (*Sphyrna lewini*)	Scuba	From December to May	Advanced	High	High	Intermediate	Western Central Pacific
Philippines	Oslob, Cebu	No	Provisioning	Whale sharks (*Rhincodon typus*)	Snorkeling	Year round	None required	Intermediate	High	Intermediate	Western Central Pacific
Philippines	The Tubbataha Reefs Natural Park	Yes	Natural aggregation	Whitetip reef sharks (*Triaenodon obesus*), grey reef sharks (*Carcharhinus amblyrhynchos*), blacktip reef sharks (*Carcharhinus melanopterus*)	Scuba	From March to June	Advanced	High	Low (only via liveaboards)	High	Western Central Pacific
Philippines	Donsol Marine Conservation Park	Yes	Natural aggregation	Whale sharks (*Rhincodon typus*)	Snorkeling	From February to May	None required	Intermediate	High	Intermediate	Western Central Pacific
Philippines	Sogod Bay, Southern Leyte	No	Natural aggregation	Whale sharks (*Rhincodon typus*)	Snorkeling	From November to May	None required	Intermediate	High	Intermediate	Western Central Pacific
Portugal	Condor and Azores Banks, Faial and Pico, Azores Islands	No	Provisioning	Blue sharks (*Prionace glauca*) and shortfin mako sharks (*Isurus oxyrinchus*)	Scuba and snorkeling	From July to September	Basic/ Intermediate	Intermediate	Intermediate	High	Northeast Atlantic
Republic of Djibouti	Bay of Ghoubbet, Gulf of Tadjourah	No	Natural aggregation	Whale sharks (*Rhincodon typus*)	Snorkeling	From November to February	None required	Intermediate	High	Intermediate	Western Indian Ocean
Republic of Palau	Blue Corner and Blue Holes, Koror	Yes	Natural aggregation	Whitetip reef sharks (*Triaenodon obesus*), grey reef sharks (*Carcharhinus amblyrhynchos*), leopard sharks (*Stegostoma Fasciatum*)	Scuba	Year round	Advanced	High	Intermediate	High	Western Central Pacific
Republic of Palau	German Channel, Koror	Yes	Natural aggregation	Whitetip reef sharks (*Triaenodon obesus*), grey reef sharks (*Carcharhinus amblyrhynchos*)	Scuba	Year round	Basic	High	High	Intermediate	Western Central Pacific

Industry	Dive site	Legal protection	Method	Species	Activity	Seasonality	Diver level	Abundance	Accessibility	Visibility	Fishing area
Republic of Palau	New Drop Off, Koror	Yes	Natural aggregation	Grey reef sharks (*Carcharhinus amblyrhynchos*)	Scuba	Year round	Basic/ Advanced	High	High	High	Western Central Pacific
Republic of Palau	Ulong Channel, Koror	Yes	Natural aggregation	Whitetip reef sharks (*Triaenodon obesus*), grey reef sharks (*Carcharhinus amblyrhynchos*)	Scuba	Year round	Advanced	High	High	Intermediate	Western Central Pacific
Republic of Palau	Ngedbus Coral Garden, Koror	Yes	Natural aggregation	Blacktip reef sharks (*Carcharhinus melanopterus*)	Scuba	Year round	Basic	High	High	Intermediate	Western Central Pacific
Republic of Palau	Ngerchong Wall, Koror	Yes	Natural aggregation	Whitetip reef sharks (*Triaenodon obesus*), grey reef sharks (*Carcharhinus amblyrhynchos*), blacktip reef sharks (*Carcharhinus melanopterus*)	Scuba	Year round	Basic/ Intermediate	High	High	High	Western Central Pacific
Republic of Palau	Shark City, Koror	Yes	Natural aggregation	Grey reef sharks (*Carcharhinus amblyrhynchos*) and great hammerhead sharks (*Sphyrna mokarran*)	Scuba	Year round	Advanced	High	High	High	Western Central Pacific
Scotland	The Hebrides	No	Natural aggregation	Basking shark (*Cetorhinus maximus*)	Snorkeling	From July to September	None required	Intermediate	High	Intermediate	Northeast Atlantic
Seychelles	Beau Vallon Bay, Mahe Island	No	Natural aggregation	Whale sharks (*Rhincodon typus*)	Snorkeling	From October to April	None required	Intermediate	High	High	Western Indian Ocean
Seychelles	Turtle Rock, Mahe Island	No	Natural aggregation	Whitetip reef sharks (*Triaenodon obesus*), tawny nurse shark (*Nebrius ferrugineus*)	Scuba	Year round	Basic	Intermediate	High	Intermediate	Western Indian Ocean
Seychelles	Shark Point, Mahe Island	No	Natural aggregation	Whitetip reef sharks (*Triaenodon obesus*), grey reef sharks (*Carcharhinus amblyrhynchos*) tawny nurse sharks (*Nebrius ferrugineus*)	Scuba	Year round	Basic	Intermediate	High	Intermediate	Western Indian Ocean
Seychelles	South Marianne Island	No	Natural aggregation	Grey reef sharks (*Carcharhinus amblyrhynchos*)	Scuba	Year round	Basic	High	High	High	Western Indian Ocean

Industry	Dive site	Legal protection	Method	Species	Activity	Seasonality	Diver level	Abundance	Accessibility	Visibility	Fishing area
Seychelles	Alphonse Island	No	Natural aggregation	Silvertip sharks (*Carcharhinus albimarginatus*), Whitetip Reef Shark (*Triaenodon obesus*), Grey Reef Shark (*Carcharhinus amblyrhynchos*)	Scuba	Year round	Basic	Intermediate	High	High	Western Indian Ocean
South Africa	Aliwal Shoal Marine Protected Area, Durban	Yes	Natural aggregation and provisioning	Blacktip sharks (*Carcharhinus limbatus*), Tiger sharks (*Galeocerdo cuvier*) and Grey nurse sharks (*Carcharias taurus*)	Cage diving, scuba diving and snorkeling	Year round	None required/ Basic	High	High	Intermediate	Southeast Atlantic
South Africa	Mossel Bay, Garden Route	No	Provisioning	White shark (*Carcharodon carcharias*)	Cage diving	Year round	None required	Intermediate	High	Low	Southeast Atlantic
South Africa	Sardine Run, Wild coast	Yes	Natural aggregation	Shortfin mako sharks (*Isurus oxyrinchus*), Blacktip sharks (*Carcharhinus limbatus*) and dusky sharks (*Carcharhinus obscurus*)	Scuba and snorkeling	From June to July	Basic	High	Intermediate	Low	Southeast Atlantic
South Africa	Gansbaai and Seal Island, False Bay	No	Natural aggregation	White shark (*Carcharodon carcharias*)	Cage diving	Year round	None required	Intermediate	High	Low	Southeast Atlantic
South Africa	Protea Banks Marine Protected Area	Yes	Natural aggregation and Provisioning	Bull sharks (*Carcharhinus leucas*), Blacktip sharks (*Carcharhinus limbatus*), Tiger sharks (*Galeocerdo cuvier*), Grey nurse sharks (*Carcharias taurus*), scalloped hammerhead (*Sphyrna lewini*), great hammerhead sharks (*Sphyrna mokarran*)	Scuba	Year round	Advanced	High	High	Intermediate	Southeast Atlantic
South Africa	Cape Point, False Bay	No	Provisioning	Blue sharks (*Prionace glauca*) and Shortfin mako sharks (*Isurus oxyrinchus*)	Cage diving, scuba and snorkeling	From November to June	None required/ Advanced	Intermediate	Intermediate	Intermediate	Southeast Atlantic
Spain	Bermeo, Urdaibai Biosphere Reserve, Basque Country	No	Provisioning	Blue sharks (*Prionace glauca*) and Shortfin mako sharks (*Isurus oxyrinchus*)	Snorkeling	From June to October	None required	Intermediate	Intermediate	Intermediate	Northeast Atlantic

Industry	Dive site	Legal protection	Method	Species	Activity	Seasonality	Diver level	Abundance	Accessibility	Visibility	Fishing area
The Bahamas	Tiger beach, Grand Bahama	Yes	Provisioning	Tiger sharks (*Galeocerdo cuvier*), lemon sharks (*Negaprion brevirostris*)	Scuba	Year round	Basic	High	Intermediate	High	Western Central Atlantic
The Bahamas	Bimini	Yes	Provisioning	Great hammerhead sharks (*Sphyrna mokarran*), tiger sharks (*Galeocerdo cuvier*), lemon sharks (*Negaprion brevirostris*) bull sharks (*Carcharhinus leucas*), caribbean reef sharks (*Carcharhinus perezii*)	Scuba and cage diving	Year round	None required/ Basic	Intermediate	High	High	Western Central Atlantic
The Bahamas	Columbus Point, Cat Island	Yes	Provisioning	Oceanic whitetip sharks (*Carcharhinus longimanus*)	Scuba and snorkeling	From March to June	Advanced	Intermediate	High	High	Western Central Atlantic
The Bahamas	Shark Wall, The Arena and The Runaway, Nassau	Yes	Natural aggregation and Provisioning	Caribbean reef sharks (*Carcharhinus perezii*)	Scuba	Year round	Basic	High	High	High	Western Central Atlantic
Tanzania	Mafia Island Marine Park	Yes	Natural aggregation	Whale sharks (*Rhincodon typus*)	Snorkeling	From October to March	None required	Intermediate	Intermediate	Intermediate	Western Indian Ocean
Thailand	Palong Wall, Phi Phi Marine Park	Yes	Natural aggregation	Blacktip reef sharks (*Carcharhinus melanopterus*)	Scuba and snorkeling	Year round	Basic	High	Intermediate	Intermediate	Eastern Indian Ocean
Thailand	The Bida's, Phi Phi Marine Park	Yes	Natural aggregation	Leopard sharks (*Triakis semifasciata*), blacktip reef sharks (*Carcharhinus melanopterus*)	Scuba and snorkeling	Year round	None required/ Advanced	High	Intermediate	Intermediate	Eastern Indian Ocean
Turks and Caicos	French Cay	Yes	Natural aggregation	Caribbean reef sharks (*Carcharhinus perezii*), nurse sharks (*Ginglymostoma cirratum*) and lemon sharks (*Negaprion brevirostris*)	Scuba and snorkeling	Year round	Basic	Intermediate	Intermediate	High	Western Central Atlantic

Industry	Dive site	Legal protection	Method	Species	Activity	Seasonality	Diver level	Abundance	Accessibility	Visibility	Fishing area
Turks and Caicos	Shark Hotel, Providenciales	Yes	Natural aggregation	Caribbean reef sharks (*Carcharhinus perezii*) and nurse sharks (*Ginglymostoma cirratum*)	Scuba	Year round	Intermediate/ Advanced	Intermediate	High	High	Western Central Atlantic
United States of America	Gulf of the Farallones National Marine Sanctuary, California	Yes	Mammal-shaped decoy	White shark (*Carcharodon carcharias*)	Cage diving	From September to November	None required	Intermediate	Low	Low	Eastern Central Pacific
United States of America	Palm Beach, Florida	No	Natural aggregation	Lemon sharks (*Negaprion brevirostris*), tiger sharks (*Galeocerdo cuvier*), sandbar sharks (*Carcharhinus plumbeus*), great hammerhead sharks (*Sphyrna mokarran*), bull sharks (*Carcharhinus leucas*), dusky sharks (*Carcharhinus obscurus*) and caribbean reef sharks (*Carcharhinus perezii*) and silky sharks (*Carcharhinus falciformis*)	Scuba, cage diving and Snorkeling	Year round	None required/ Basic	High	High	High	Western Central Atlantic
United States of America	Oahu, Hawai	No	Natural aggregation	Galapagos sharks (*Carcharhinus galapagensis*) and Sandbar sharks (*Carcharhinus plumbeus*)	Cage diving and snorkeling	Year round	None required	Intermediate	High	High	Eastern Central Pacific
United States of America	Fish Rain, Molokai, Hawai	Yes	Natural aggregation	Scalloped hammerhead sharks (*Sphyrna lewini*), grey reef sharks (*Carcharhinus amblyrhynchos*) and Galapagos sharks (*Carcharhinus galapagensis*)	Scuba	Year round	Advanced	High	Intermediate	High	Eastern Central Pacific
United States of America	San Diego, California	No	Provisioning	Blue sharks (*Prionace glauca*) and shortfin mako sharks (*Isurus oxyrinchus*)	Snorkeling	Year round	None required	Intermediate	Intermediate	Intermediate	Eastern Central Pacific
United States of America	Rhode Island, New England	No	Provisioning	Blue sharks (*Prionace glauca*) and shortfin mako sharks (*Isurus oxyrinchus*)	Scuba, cage diving and snorkeling	From June to September	None required/ Basic	Intermediate	Intermediate	Intermediate	Northwest Atlantic

Industry	Dive site	Legal protection	Method	Species	Activity	Seasonality	Diver level	Abundance	Accessibility	Visibility	Fishing area
United States of America	Montauk, New York	No	Provisioning	Blue sharks (*Prionace glauca*) and shortfin mako sharks (*Isurus oxyrinchus*)	Cage diving	From June to September	None required	Intermediate	Intermediate	Intermediate	Northwest Atlantic
United States of America	Nantucket and Cape Cod, Massachusetts	No	Provisioning	Blue sharks (*Prionace glauca*) and shortfin mako sharks (*Isurus oxyrinchus*)	Cage diving and scuba	From June to October	None required/ Basic	Intermediate	Medium	Medium	Northwest Atlantic
United States of America	Atlas, Caribsea and Aeolus, Outer Banks, Monitor National Marine Sanctuary, North Carolina	Yes	Natural aggregation	Grey nurse sharks (*Carcharias taurus*)	Scuba	From June to September	Intermediate	High	Intermediate	Intermediate	Northwest Atlantic
United States of America	Catalina Island Marine Protected Areas, California	Yes	Provisioning	Blue sharks (*Prionace glauca*) and shortfin mako sharks (*Isurus oxyrinchus*)	Cage diving	Year round	None required	Intermediate	Intermediate	High	Eastern Central Pacific