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Análisis de características biológico-pesqueras del pargo manchado (*Lutjanus guttatus* (Steindachner, 1869) y tendencias socio-ecológicas de la pesca artesanal con líneas de fondo en el distrito de Bejuco, Pacífico de Costa Rica.

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2

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El uso de líneas de fondo para pescar pargos manchados es sumamente desgastante para los pescadores. Ellos pescan hasta 14 horas (toda la noche). Luego tienen que preparar el pescado y venderlo. Después, se arreglan las líneas, se cambian renales gastados, se corta la carnada y se pone en los anzuelos. A pesar de todo el trabajo que requieren realizar, ellos tuvieron la disposición de brindarme información acerca de su pesquería y por eso estoy muy agradecido.

INDICE

Análisis de características biológico-pesqueras del pargo manchado (*Lutjanus guttatus* (Steindachner, 1869) y tendencias socio-ecológicas de la pesca artesanal con líneas de fondo en el distrito de Bejuco, Pacífico de Costa Rica.

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RESUMEN GENERAL

El presente estudio analizó la base de datos pesqueros de la Asociación Programa Restauración de Tortugas Marinas (PRETOMA), tomada entre 2007-2013, para determinar las características biológico-pesqueras de la población del pargo manchado (*Lutjanus guttatus*) del distrito Bejuco, Pacífico de Costa Rica. La información recabada reunió las características de las capturas incidentales de la pesquería con líneas de fondo y la selectividad de esta técnica. Posteriormente se aplicó una encuesta a la población de pescadores del distrito (n=49), junto con entrevistas abiertas y grupos focales para identificar el perfil sociodemográfico del grupo del estudio y determinar tendencias socio-ecológicas de este sector. Finalmente se preparó un conjunto de recomendaciones de manejo, basado en los resultados de la aplicación de la técnica de semáforo a los indicadores derivados de los estudios. El análisis de las características biológico-pesqueras reveló que los pargos tienen una longitud total mayor en el 2013 que en el 2007 y su mortalidad total es más baja que en otras poblaciones de esta especie previamente estudiadas en Costa Rica. Estos resultados dan evidencia que la población de pargos de Bejuco es menos explotado que otras poblaciones de la región y podría deberse a la presencia de las dos Áreas Marinas Protegidas (AMPs) del distrito. El reclutamiento de *L. guttatus* a la pesquería demostró dos picos significativos durante el año (marzo y octubre) y se estimó que las reclutas tienen en promedio 4.43 años. Un poco más que la mitad (51.5%) de las capturas con líneas de fondo son *L. guttatus*, de las cuales 15.4% son inmaduras. Varias especies de anguilas, congrios y morenas del orden Anguiliformes componen un 25.9% de las capturas totales. Se estima que un 37% de las capturas totales son descartadas, pero hay que considerar que el estudio no incluyó porcentajes de consumo local. La situación económica de los pescadores del distrito de Bejuco se puede categorizar en un status de pobre sin llegar a la pobreza extrema. Ellos perciben que sus ganancias son cada vez menores y luchan por cubrir sus gastos familiares. Sin embargo, está situación es sobrellevada por el hecho de vivir en una comunidad unida, segura y tranquila. Al mismo tiempo, están preocupados por la viabilidad a largo plazo de la industria pesquera causada por una carencia de control y monitoreo, por parte del gobierno nacional, de la pesca destructiva e ilegal. Por ser una pesquería mixta (líneas de fondo, trasmallos y redes de arrastre) se recomendó el seguimiento de la recolecta de información científica entre pescadores e investigadores para poder realizar un análisis del stock de la especie en un futuro cercano. Se recomendó el desarrollo de mercados alternativos para mejorar sus ganancias y el desarrollo de una sola asociación con la capacidad de desarrollar un sistema comunitario de manejo de la pesca. Por último se recomendó que los pescadores hagan un plan de manejo pesquero local y una campaña exigiéndole al gobierno nacional mayor participación en la vigilancia y protección del recurso pesquero local a través del desarrollo de una nueva área de manejo que proteja mejor sus intereses.

ABSTRACT

The following study analyzed the Sea Turtle Restoration Project's (PRETOMA) fisheries database from 2007-2013 to determine the population dynamics of the spotted rose snapper (*Lutjanus guttatus*) in the district of Bejuco, Pacific Costa Rica, the bottom-longline fishery's catch composition, and the gear type's selectivity. A questionnaire was also applied to the district's bottom-longline population (n=49), along with open interviews and focus groups in order to identify the study group's socio-demographic profile and to determine the sector's socio-ecological tendencies. A set of management recommendations was then developed based on the results of the traffic light method applied to indicators derived from these studies. The Bejuco snapper population dynamics results revealed that the individuals are larger in 2013 than they were in 2007, and the population's total mortality is lower than in previously studied Costa Rican populations. This is evidence that the Bejuco snapper population is less exploited than others in the region and might be an effect of the district's two marine protected areas (MPAs). *Lutjanus guttatus* recruitment into the fishery demonstrated two significant seasonal peaks (March and October), and a growth curve established for the species estimated recruits to be an average of 4.43 years of age. Slightly over half of bottom-longline captures (51.5%) were *L. guttatus*, of which 15.4% were immature. Various species of eels, congers and morays from the Anguilliformes order made up 25.9% of the entire catch. An estimated 37% of the catch was discarded, though the study did not take into account local consumption trends. In terms of the project's social study, fishers live within the boundaries of poverty but not extreme poverty. They believe their earnings are consistently decreasing and that it is increasingly more difficult to provide for their families. Despite this, fishers have created a united, safe, and tranquil community within which to live. Notwithstanding, there is concern over the long-term viability of their industry because of a lack of sufficient control and monitoring of destructive, illegal coastal fisheries on the part of the national government. Because this is a mixed fishery (bottom-longlines, gillnets, trawl nets), it was recommended that fishers continue their data collection efforts with researchers in order to perform a *L. guttatus* stock assessment in the near future. The development of alternative markets to improve fisher earnings was recommended along with a consolidation of the existing three fishing associations into a single association with the capacity to develop a community based management system. Lastly, fishers were recommended to develop a local fisheries management plan and a campaign that demands that the national governmental improve its enforcement and monitoring of local fishing resources through the development of a new management area that better protects their efforts.

INTRODUCCIÓN GENERAL

En las últimas décadas, las regiones tropicales han tenido un papel relevante en el desarrollo del esfuerzo pesquero global (Swartz, Sala, Tracey, Watson, Pauly, 2010; Anticamara, Watson, Gelchu, & Pauly, 2011; FAO, 2012; Gagern & van den Bergh, 2013). Son reconocidas por su importancia en la seguridad alimenticia y representan áreas de gran producción. Desafortunadamente los ecosistemas tropicales heterogéneos se han caracterizado por una escasez de conocimiento de las características biológicas de sus recursos pesqueros y la ausencia de estrategias de manejo eficientes (Mora et al., 2009; Worm et al., 2009; Andalecio, 2010; Gagern & van den Bergh, 2013). Las pesquerías de estas regiones están frecuentemente caracterizadas por la sobreexplotación de los recursos marinos renovables debido a la sobre pesca, la destrucción de hábitats causada por métodos de pesca destructivos y la pesca ilegal (Eggert & Greaker, 2009; Andalecio, 2010).

Estas deficiencias en el manejo de la pesquerías tropicales contribuyen a la situación crítica en la que se encuentra pesca a nivel mundial y que se refleja en que un 77% de las poblaciones de peces comerciales están siendo explotadas al máximo de su capacidad o incluso han sido sobreexplotadas y agotadas por completo (FAO, 2011). Lo que es más, este tipo de sobreexplotación no solo tiene repercusiones ambientales, sino también sociales debido a las importantes fuentes de empleo e ingresos que la industria pesquera proporciona. Se estima que un total de 520 millones de personas, o un 7.9% de la población mundial, depende económicamente de la pesca, la mayoría de ellos en países subdesarrollados (FAO, 2011).

El manejo efectivo de los recursos pesqueros requiere un balance de estrategias tanto de conservación de las especies como del aprovechamiento sostenible de su entorno (Bunce & Pomeroy, 2003). En términos de la pesca, esta perspectiva otorga prioridad a la protección de los recursos acuáticos de las áreas costeras y a la vez, busca el mantenimiento de las opciones sociales y económicas de las generaciones futuras de sus asociados (FAO, 1995; Rubinoff & Celis-Salgado, 2005). La función de esta estrategia (el manejo responsable de los recursos pesqueros) se destaca en una industria pesquera que busca el equilibrio entre el total de captura, las tasas de reproducción y la utilización adecuada de prácticas de pesca, las cuales no deben ser nocivas para el ecosistema (FAO, 1995; Costa Rica, 2008).

La información primordial requerida para el desarrollo de este tipo de estrategia de manejo está basada en el entendimiento de las características de las poblaciones de las especies objetivo de pesca y la composición de las capturas incidentales que resultan de la misma (Caddy, 1989; Sparre & Venema, 1997; Jackson et al., 2001; Seijo, Pérez, & Caddy, 2004; Pauly, Watson, & Alder, 2005). Los modelos de las dinámicas poblacionales de las especies objetivo proveen los primeros pasos hacia el mantenimiento o restablecimiento a ecosistemas funcionales debido a su valiosa información acerca de la abundancia de las especies explotadas, la cual es necesaria para el diseño de estrategias de manejo de una especie determinada (Touzeau & Gouzé, 1998; Pope, Lochmann, & Young, 2010). El conocimiento de la biología y ecología de las especies de alto valor económico ayuda al desarrollo de estrategias de manejo, sin embargo las capturas de fauna acompañante ha sido un punto de enfoque emergente en la discusión de la problemática pesquera (Davies, Cripps, Nickson, & Porter, 2009; Andalecio, 2010).

A lo largo del tiempo, la captura indiscriminada, en donde los organismos no aportan valor económico en la actividad pesquera, razón por la cual son posteriormente descartados, promueve la sobrepesca (Alverson, Freeberg, Pope, & Murawski, 1994; Eggert & Greaker, 2009). Esta práctica, conocida como pesca incidental o mortalidad incidental de especies no utilizadas ni manejadas, representa una amenaza a la productividad de muchos ecosistemas marinos, a pesar de ser un tema de preocupación por la política pesquera (Davies et al., 2009; Andalecio, 2010). Independientemente si la captura incidental se vende o se bota al mar, ésta práctica impacta negativamente los rendimientos pesqueros, las ganancias de los pescadores y las funciones de ecosistemas marinas (Alverson et al., 1994; Davies et al., 2009; Eggert & Greaker, 2009). En el contexto global, las capturas incidentales descartadas representan entre 27 y 40.4% de las capturas marinas globales (Alverson et al., 1994; Kelleher, 2005; Davies et al., 2009). El problema se empeora en el caso de las pesquerías tropicales, costeras, complejas y heterogéneas, donde existe poco monitoreo de la fauna acompañante y por lo tanto un escaso conocimiento de las capturas totales (FAO, 2003). Debido a lo anterior, la minimización de las tasas de las capturas incidentales, y el impacto que tiene en las especies individuales, ha llegado a ser un importante componente del manejo pesquero (Andalecio, 2010).

Las capturas incidentales normalmente resultan con técnicas pesqueras y equipos no capaces de seleccionar exclusivamente a las especies de objetivo de la pesquería. (Prellezo &

Gallastegui, 2008; Davies et al., 2009; Andalecio, 2010). Sin embargo, existe evidencia de que las cantidades de estos tipos de capturas han disminuido a niveles globales (Kelleher, 2005). Una de las mayores razones de este hecho, es el desarrollo e implementación de equipos y estrategias de pesca más selectivos, los cuales no solo reducen los desechos asociados a las capturas incidentales, sino también mitigan sus impactos a las especies protegidas y/o en peligro de extinción y a la vez mejoran la función y salud del ecosistema (FAO, 2003; Pikitch et al., 2004; Kelleher 2005). El conocimiento de estrategias de pesca y la determinación de la selectividad de las artes, son de alta importancia para los manejadores pesqueros preocupados por el desarrollo de estrategias de manejo y puntos biológicos de referencia (Myers & Hoenig 1997; Huse, Løkkeborg, & Soldal, 2000). Se considera que generalmente la pesca de pequeña escala genera tasas de fauna acompañante más bajas que la pesca industrial y por eso es más selectiva. No obstante, la selectividad fluctúa mucho entre la pesca artesanal por el rango amplio de técnicas que se aplican (FAO, 1984).

Si bien es cierto que la información científica de las especies objetivo, así como de las capturas de los demás organismos puede aportar al desarrollo de estrategias responsables para la industria pesquera, la información social sobre el conocimiento ecológico por parte de pescadores también aporta a la toma de decisiones de este sector (Fischer, 2000; Gosse, Wroblewski, & Neis, 2001; Berkes & Folke, 2002; Murray, Neis, & Johnsen, 2006; Lutz & Neis, 2008; Nenadovic, Johnson, & Wilson, 2012). Esta sabiduría por parte de los pescadores acerca de sus relaciones socio-ecológicas con su entorno y más específicamente del comportamiento de algunas especies de peces y sus interacciones en áreas específicas, podría ser usado para el establecimiento de una línea base en la pesquería, particularmente cuando no existe suficiente información científica sobre el estado de las poblaciones de peces, no solo de las especies objetivo sino también de las capturas incidentales (Pauly, 1995). A la vez, el manejo adecuado de la pesca y sobre todo el sector artesanal, requiere un enfoque interdisciplinario que no solo incluya información sobre los entornos biofísicos de la fauna marina, sino también estudios de la dinámica demográfica y socio-económica de los que aprovechan el recurso, en este caso los pescadores (Chuenpagdee et al., 2005; Gasalla, Rodrigues, Duarte, & Sumaila, 2010).

Incluir el punto de vista de los pescadores en el proceso de la toma de decisiones, la evaluación de impactos sociales y económicos del área pesquera permitirá el desarrollo apropiado de esta industria. Investigadores, manejadores pesqueros, miembros de gobiernos locales y nacionales entre otros, se encuentran en la búsqueda permanente de estrategias que propicien el mejoramiento de las condiciones de vida de los pescadores y su entorno socioeconómico (Salas, Chuenpagdee, Charles, & Seijo, 2011). A pesar de ello, se considera que la atención puesta sobre el uso de herramientas y metodologías que brinden información, tanto ecológica como socioeconómica, es limitada, situación que ha llevado a un conocimiento insuficiente del manejo apropiado del recurso pesquero (Salas, Chuenpagdee, Seijo, & Charles 2007; Leite & Gasalla, 2013).

Las preocupaciones mundiales sobre el estado de la pesca y los recursos pesqueros están promoviendo el desarrollo de métodos de manejo que abarquen el aprovechamiento responsable, la eficiencia económica y la equidad al acceso a los recursos tanto para la pesca industrial como para la pesca artesanal (Cochrane, 1999). En este entorno, la necesidad de fortalecer la pesca artesanal como estrategia de manejo emergente es cada vez más reconocida (Pauly, 1997; Allison & Ellis, 2001). Estas tendencias son de gran importancia a lo largo de la costa pacífica de Costa Rica donde se encuentran comunidades de pescadores artesanales de pequeña escala, las cuales son vulnerables cultural, económica y ambientalmente, debido a una serie de variables vinculadas al desarrollo turístico, la sobrepesca, la pesca ilegal, la contaminación y los efectos del cambio climático (Alvarado, Herrera, Corrales, Asch, & Paaby, 2010; Alvarado, Cortés, Esquivel, & Salas, 2012).

La industria pesquera ubicada en el litoral pacífico de Costa Rica propicia un 97% de todos los productos marinos capturados en el país (González et al., 1993; Araya et al., 2007). Con una longitud de 1,254 km, la costa Pacífica del país representa una gran diversidad de hábitats que incluyen: playas rocosas, arenosas y lodosas, acantilados, manglares, fondos blandos, estuarios, arrecifes coralinos, pastos marinos, un fiordo tropical, islas, golfos y bahías (Nielsen-Muñoz & Quesada-Alpízar, 2006; Wehrtmann & Cortés, 2009). Su geografía ya mencionada forma ecosistemas acuáticos en los que se encuentran hasta 80 especies de importancia comercial como: meros (Serranidae), corvinas (Scianidea), róbalos (Centropomidae), pargos (Lutjanidae), langostas (Palinuridae), camarones (Penaeidae, Solenoceridae, Pandalidae), cambutes (Strombus) y otros de menor valor comercial (González et al., 1993; SINAC, 2007; Wehrtmann & Cortés, 2009; Wehrtmann & Nielsen-Muñoz, 2009).

La industria pesquera comercial en Costa Rica, según datos del Instituto Costarricense de Pesca y Acuicultura (INCOPESCA) citado en Araya et al. (2007), está formado principalmente por 4,000 pescadores artesanales. Como afirman Chang & del Río (2004), la práctica de la pesca artesanal en Costa Rica es una actividad que demuestra "un conjunto de conocimientos conscientes e inconscientes que permiten la práctica de una técnica aprendida mediante la oralidad o la observación, lo que permite concebir a la pesca artesanal como una expresión popular de la cultura local". Las descargas anuales de la pesca artesanal en la costa pacífica incrementaron considerablemente desde que inició la toma de datos en 1952. La actividad llegó a su pico en el 2001 con aproximadamente 25.000 toneladas de especies marinas capturadas, sin embargo, las descargas realizadas en el 2007 muestran un peso de aproximadamente 16.000 toneladas (Araya et al., 2007). Esta cifra demuestra que la disminución de la industria pesquera costarricense sigue a las pautas internacionales (Araya et al., 2007).

La pesca artesanal en Costa Rica está formada por la de pequeña escala. En este contexto, la distancia de la costa autorizada para la pesca artesanal de pequeña escala no es superior a las tres millas náuticas (Chang & del Río, 2004; Costa Rica, 2005; Araya, s.f.). Entre las técnicas más utilizadas por los pescadores artesanales de pequeña escala es la línea de fondo, generalmente usada para la captura de organismos como pargo manchado, congrio rosado, anguila, cabrilla, corvina agria, etc. (Araya et al., 2007). Generalmente, la línea mide entre 200 y 1.500 metros de largo (depende de la zona) con anzuelos y plomos colocados cada cinco metros para que se quede en el suelo marino (Araya et al., 2007; Mongeon, Graneka, & Arauz, 2013).

Con respecto a las pesquerías artesanales tropicales, la Organización de las Naciones Unidas para la Agricultura y la Alimentación (FAO) considera que las líneas de fondo son menos selectivos comparados con otros técnicas que resultan en menos capturas incidentales como la cuerda de mano, líneas arrastradas y la pesca con caña (FAO, 1984). Al contrario a los datos presentados por la FAO (1984), en Costa Rica se cree que la técnica es altamente selectiva (Arauz, López, Zanella, & López, 2008) y un componente a la pesca responsable (INCOPESCA, 2008). No obstante, las líneas de fondo son unas de las técnicas más tradicionales usadas por pescadores a lo largo de la costa pacífica del Centroamérica (OSPESCA, 2009).

Uno de las zonas en las cuales se emplea la línea de fondo es la región de la costa suroeste de la Península de Nicoya, cantón de Nandayure, distrito de Bejuco, donde se ubican dos comunidades pescadores artesanales de pequeña escala (Solís & Fonseca, 2008). En términos del desarrollo económico de la zona donde están ubicadas estos grupos demográficos, la pesca es uno de los principales pilares de la economía local (Solís & Fonseca, 2008). Los pescadores realizan sus actividades de pesca dentro y en las afueras del área marina protegida (AMP) de multi-uso del Refugio Nacional de Vida Silvestre Caletas-Arío y del Refugio Nacional de Vida Silvestre Camaronal. Han asumido compromisos, los cuales permiten que ellos realicen sus actividades dentro de los refugios, mientras la abundante riqueza marina de especies de interés comercial dentro y en los alrededores de ambas AMPs, atrae presión pesquera por otras comunidades de pescadores alejadas (Solís & Fonseca, 2008). Por lo general, ellos dirigen sus esfuerzos hacia la captura del pargo manchado (*Lutjanus guttatus*), pero a la vez se captura corvina, jurel, róbalo, langostas, entre otras especies realizando viajes de pesca nocturnos (MINAE, 2005).

Lutjanus (Bloch, 1790) es el género más grande de la familia Lutjanidae, formada por 70 especies (Allen, White, & Erdmann, 2013), con *Lutjanus guttatus* (Steindachner, 1869) siendo uno de los más comunes y abundantes especies de Lutjanidae en el Pacífico Tropical Oriental donde sus poblaciones se desplazan del Golfo de California a Perú (Fisher et al., 1995; Vargas, 1998-99; Rojo-Vásquez, Arreguín-Sánchez, Godínez-Domínguez, & Ramírez-Rodríguez,1999; Andrade-Rodriguez, 2003; Chiappa-Carrara, Rojas, & Mascar, 2004; Rojas, Maravilla, & Chicas, 2004). Aunque variable, la mayoría de los individuos de *L. guttatus* presenta una coloración amarillenta con aletas rosadas o rojas, con hocico puntiagudo y una boca grande y alargada (Allen & Robertson 1994; García, 2008). Es un pez carnívoro, el cual consume predominantemente crustáceos (Penaeidae, Sicyoniidae, Squillidae, Callianassidae, Portunidae, Dynomenidae) y que ocupa las aguas costeras de poca profundidad de los estuarios y manglares a aguas de media profundidad con fondos rocosos, los cuales corresponden a sus diferentes estados de vida (Rojas, 1996; Rojas et al., 2004). En Costa Rica el estado natural de estos ecosistemas se ve comprometido por el desarrollo costero, la contaminación, la sobrepesca y la captura incidental de juveniles por la pesca de camarón de arrastre, entre otras técnicas no sostenibles (Rojas, 1996).

A pesar de ser una especie de alta importancia económica para miles de pescadores artesanales en Costa Rica, existe información técnica insuficiente sobre las poblaciones de *L. guttatus*. Además, esta falta de conocimiento está complementada por la ausencia de estudios sobre las observaciones y opiniones de los mismos pescadores artesanales acerca del estado de sus pesquerías y el impacto que sus acciones tienen sobre el recurso (González et al., 1993; Chang & del Río, 2004). Esto genera un conflicto de intereses principalmente porque si no se entiende o no se ve el impacto que se tiene sobre algo, ¿cómo va a mejorar? Existe una gran necesidad económica, social y ambiental de conocer más sobre el estado de la población de pargo manchado, las capturas incidentales que resultan del uso de las líneas de fondo y cómo los pescadores artesanales de Costa Rica perciben sus impactos sobre la población de esta especie para poder manejar la pesca de *L. guttatus* de una forma más sostenible. Es por eso que una de las preguntas principales del presente estudio es: ¿cuál es el nivel de sostenibilidad percibido por los pescadores del pargo manchado con líneas de fondo en el distrito de Bejuco en relación con las características de la población del pargo manchado y la fauna acompañante en Costa Rica? Para encontrar una respuesta a esta pregunta, se analizó las características biológico-pesqueras de la población del pargo manchado, los componentes principales de la fauna acompañante y el nivel de sostenibilidad pesquero percibido por los usuarios de líneas de fondo en Bejuco, Pacífico de Costa Rica, para entender mejor las relaciones entre el estado del recurso más valioso de la pesca y cómo los pescadores lo perciben.

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CAPÍTULO I

Population dynamics and growth of the spotted rose snapper *Lutjanus guttatus* (Steindachner, 1869) from the northern Pacific coast of Costa Rica, Central America

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Abstract

For bottom-longline fishers in the district of Bejuco, Costa Rica, the most economically important species is the spotted rose snapper (*Lutjanus guttatus*). In this study we define *L. guttatus* population dynamics for the exploited Bejuco stock. We analyzed 10815 individuals of *L. guttatus* collected by the Sea Turtle Restoration Program (PRETOMA) during local fishing trips and dockside landings from July 2007 to October 2013. Average yearly total length, weight/length relationship, growth parameters, monthly length frequencies, sex ratio, bottom-longline selectivity, mortality, and recruitment were all calculated and compared with the results of other *L. guttatus* studies along the Pacific coast of Central and South America. The average total length for the species was 39.9 cm (standard error ± 0.4) and varied between yearly averages of 38.0 cm in 2010 and 41.9 cm in 2013. This represents a significant increase in snapper size over the six year period, something that could be attributed to the presence of two multi-use marine protected areas located inside the fishing grounds. Snapper growth parameters varied depending on the methods used to calculate them. These inconsistencies were also noted between different *L. guttatus* studies, meaning that the method used to calculate the species' growth could account for differences between published studies. There was no significant difference in the number of males and females observed during the study. *L. guttatus* recruitment demonstrated peaks in March and October and was similar to other published studied from Costa Rica. Regarding maturity, 17.1% of females and 13.7% of males captured with bottom-longlines in Bejuco were immature. The species exploitation level (E=0.44) was at the high end of what is considered a suitable range. This level was lower than the only other reported value in Costa Rica, but within average levels for Central and South America.

Key words

Tropical marine fisheries, population dynamics, data-deficient fishery, Lutjanidae, *Lutjanus guttatus*, Costa Rican artisanal fisheries

INTRODUCTION

Over the last few decades, tropical regions have played an increasingly important role in the development of the global fishing effort (Swartz, Sala, Tracey, Watson, & Pauly, 2010; Anticamara, Watson, Gelchu, & Pauly, 2011; Gagern & van den Bergh, 2013). While an important contributor to global food security, these increased production demands have unfortunately occurred in heterogeneous tropical ecosystems characterized by a lack of sufficient data required to perform traditional stock assessments and weak or non-existing management strategies (Mora, Myers, Coll, Libralato, & Pitcher, 2009; Worm et al., 2009; Andalecio, 2010; Gagern & van den Bergh, 2013). In addition and often as a consequence of these limitations, fisheries in these regions are often characterized by an overexploitation of renewable marine resources through overfishing, habitat destruction from destructive fishing methods, and illegal fishing (Eggert & Greaker, 2009; Andalecio, 2010).

With the possibility of climate change factors also contributing to the reduced productivity of tropical coastal ecosystems (Doney et al., 2012), understanding the population dynamics of commercially exploited fish species plays an important role in the process of improving the fishery's management (Caddy, 1989; Sparre & Venema, 1997; Jackson et al., 2001; Seijo, Pérez, & Caddy, 2004; Pauly, Watson, & Alder, 2005). Population dynamic models provide an opportunity towards the maintenance or re-establishment of functional ecosystems through the incorporation of valuable information regarding fish abundance, mortality and ecology that is needed to develop appropriate harvest strategies for a given species (Touzeau & Gouzé, 1998; Pope, Lochmann, & Young, 2010).

Many of these models, however, require large data sets often not available for managers to analyze and are commonly only accessed by geographically extensive, large-scale fisheries (Cochrane, 1999; Prince, Dowling, Davies, Campbell, & Kolody, 2011). But a lack of fishery information does not suppress the need for determining harvest levels or setting overfishing thresholds for commonly fished species (Honey, Moxley, & Fujita, 2010). In fact, most fisheries around the world are considered to be data-deficient, though this does not take away the importance of their management (Honey et al., 2010). As global overfishing continues, the need to develop and implement assessment techniques applicable to more of the world´s fisheries, including tropical, small-scale, coastal fisheries, grows in importance (Johannes, 1998; Prince, 2010).

Because of their widespread distribution in tropical and subtropical marine waters, habitat preference for coastal reefs, and demersal nature, members of the Lutjanidae family, commonly referred to as snappers, are an important component of tropical artisanal fisheries (Allen, 1985; Allen & Robertson, 1994; Fischer et al., 1995). Currently, this family is comprised by 17 genera and 109 species (Allen, White, & Erdmann, 2013). Due to the prevalence of snappers in small-scale line and net fisheries and their small contribution to commercial fisheries, there exist limited catch statistics for this socio-economically important fish resource (Allen, 1985).

Lutjanus (Bloch, 1790) is the largest genus in the Lutjanidae family with 70 species (Allen et al., 2013), with the spotted rose snapper *Lutjanus guttatus* (Steindachner, 1869) being one of the most common and abundant species of Lutjanidae in the Eastern Tropical Pacific, occupying shallow to medium depth subtropical coastal waters stretching from the Gulf of California to Peru (Fischer et al., 1995; Vargas, 1998-99; Rojo-Vásquez, Arreguín-Sánchez, Godínez-Domínguez, & Ramírez-Rodríguez, 1999; Andrade-Rodríguez, 2003; Chiappa-Carrara, Rojas, & Mascar, 2004; Rojas, Maravilla, & Chicas, 2004). Spotted rose snappers are carnivorous fish that feed predominantly on crustaceans (Squillidae, Portunidae, Dynomenidae, Penaeidae, Sicyoniidae, Callianassidae) and are found in a wide range of habitats, including shallow waters of estuaries and mangroves and deeper waters with rocky substrates, that correspond to different life cycle stages (Rojas, 1996a; Rojas et al., 2004).

In Costa Rica the natural state of these ecosystems is increasingly compromised by coastal development, pollution, and the use of trawl nets and other destructive fishing gear types (Rojas, 1996a). Being one of the most fished species by small-scale coastal fishers throughout Central America, *L. guttatus* is of high economic importance, if not the highest importance, to artisanal fishing communities in Costa Rica (González et al., 1993; Rojas, 1996a; Vargas, 1998-99; Rojas et al., 2004). While its global populations are not considered to be threatened or in danger of extinction, coastal community members are confronting increased economic difficulties and rising instances of poverty attributed to decreasing catch amounts both in this country and along the Central American Pacific coast in general (Rojas, 1996a; Rojas et al, 2004; Araya et al., 2007; Herrera-Ulloa, Chacón-Guzmán, Zúñiga-Calero, Fajardo, & Jiménez-Montealegre, 2009; IUCN, 2013). Given that small-scale artisanal fishers in coastal communities are already culturally, economically, and environmentally vulnerable due to a series of variables including tourism development, overfishing, illegal fishing, and the effects of climate change, further negative changes could dismember local spotted rose snapper populations even further (Rojas, 1996b; Quesada-Alpízar, 2004; Alvarado, Herrera, Corrales, Asch, & Paaby, 2010).

Because of this situation, the Costa Rican Fisheries and Aquaculture Institute (INCOPESCA), Costa Rica's national fisheries governing entity, created Responsible Marine Fishing Areas (RMFA). The management tool is based on the FAO's Code of Conduct for Responsible Fisheries and is intended to become a zoning instrument regulating small-scale artisanal fishing (SSF) activities within a designated area (FAO, 1995; INCOPESCA, 2008). Many SSF communities in Costa Rica are currently interested in promoting the creation of such areas where their fishing activities occur; however, they lack sufficient technical information to determine where or not their localized efforts constitute a responsible fishery. One example of this type of community is the Bejuco bottom-longline snapper fishery whose members have been working with researchers to collect catch data since 2007.

By defining *L. guttatus* population dynamics for the exploited stock located along the southwestern Nicoya Peninsula, Pacific coast of Costa Rica, this study aimed to generate solid information that will contribute to the determination of sustainable yields and responsible management strategies for this fishery in the near future. Furthermore, because of their tendency to be less industrialized in scale, snapper fisheries have often been overlooked and gone unassessed. The present study provides a data collection and analysis model that can be replicated to other small-scale fisheries for this species as well as others.

MATERIALS AND METHODS

Study area

The present study of *L. guttatus* population dynamics was carried out on the northern Pacific coast of Costa Rica in the district of Bejuco, located along the southwestern Nicoya Peninsula, (Fig. 1).

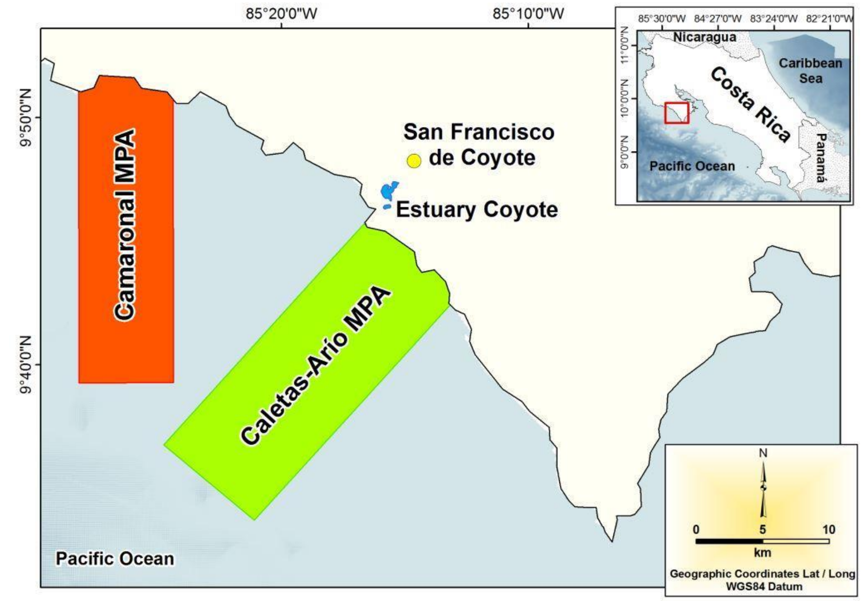

Fig. 1. Site map of the study's area, District of Bejuco, Pacific coast of Costa Rica

Data collection

Data collection from the spotted rose snapper catch was performed by a variety of consultants and interns from the Sea Turtle Restoration Program (PRETOMA), a Costa Rican marine conservation non-profit, from July 2007 to October 2013. Its members worked closely with fishers from the district's three bottom-longline artisanal snapper fishing association. The snapper catch was registered onboard local fishing boats during nightly trips to various fishing sites located in and between the fishing ground's two marine protected areas (MPAs) (Fig. 1). Landing data were also collected at the district's two traditional dock and production facilities. Morphometric variables including *L. guttatus* total length (TL; from 2007to 2013) in cm, total weight (TW) in g, and snapper sex were recorded throughout the data-collecting period. Sampling depth varied from 15 to 45 m, covering the adult depth range for this species (Allen, 1985). Snapper catch observations were made year round; however, there were several months when data was not collected and/or fishing activity did not occur.

Total length comparison

The average TL in cm for snappers caught with bottom-longlines was calculated, along with the maximum and minimum lengths for each year in order to determine yearly trends in snapper size during the sampling period. Results from this analysis were represented as box and whiskers plots. A Mann-Whitney pairwise comparison test was applied to determine whether or not average snapper TLs varied significantly from year to year, as well as from the beginning of the data set (2007) to the final year of analysis (2013).

The National Oceanic and Atmospheric Administration's (NOAA) Oceanic Niño Index (ONI) was consulted for changes in equatorial Pacific water temperature caused by El Niño and La Niña events during 2007-2013 (NOAA, 2014). These results were compared to average yearly snapper TLs to assess possible changes with these climatic events.

We used the data provided by Rojas (1996b) on *L. guttatus* sizes at first reproduction for the Gulf of Nicoya, Costa Rica, to estimate the Bejuco bottom-longline snapper fishery's selectivity as a percentage of captured immature males and females.

Weight/length relationship
Snapper growth in terms of its relation between an individual's total length and its total weight was calculated with data from 2007-2013 using the formula:

$$TW = aTL^b$$

where *a* is the Y-intercept and *b* is the slope of the curve for the growth relationship (Ricker, 1975; Sparre & Venema, 1997). Because Andrade-Rodríguez (2003) reported no statistical significance of difference between male and female spotted snapper growth curves, snapper sexes were pooled for this operation. The difference between observed and expected values was analyzed using the Solver tool from Excel.

Monthly length-frequency analysis in 1 cm class sizes
Snapper TLs data (pooled sexes) for a 12-month period (July 2007 through June 2008), representing the most complete data series recorded, were grouped into 1 cm size classes according to methods described by Bhattacharya (1967). Data were plotted as monthly length-frequency histograms to analyze the population structure. The length-frequency data were then imported into the FiSAT II software package and submitted to a direct fit analysis with the Elefan I routine to determine the maximum theoretical length a snapper can reach (L_∞) and the species' growth rate (*K*) (Pauly & David, 1981; Gayanillo, Sparre, & Pauly, 1995; Sparre & Venema, 1997). Data from other time periods were also calculated and inputted into Elefan I in order to identify a time series that yielded L_∞ and *K* values that more closely reflected those from other *L guttatus* studies in the region; however, these subsequent attempts produced outlandish results and were not used in subsequent procedures.

Growth curves
Length measurement data (July 2007 through June 2008) was used to calculate the growth parameters L_∞, *K* and t_0 via Excel and its Solver tool (Sparre & Venema, 1997). These parameters were then inputted into the von Bertalanffy growth function (VBGF) used to show species growth:

$$Lt = L_\infty \left(1 - e^{\left(-K\left(t - t_0\right)\right)}\right)$$

where L_∞ is the theoretical maximum length that an individual can reach if lived indefinitely (asymptotic length), *K* is a growth coefficient or curvature parameter that measures the rate at which maximum size is reached, *t* is the predicted age, and t_0 is an individual's length at age zero. Growth parameter values for the Solver analysis and the Elefan I analysis were compared in order to identify similarities and discrepancies.

Mortality
No published information is available regarding mortality patterns at age for Eastern Tropical Pacific spotted snapper fisheries. Therefore, a length-converted (to age) catch curve based on the July 2007 through June 2008 length frequency progression, using Elefan I generated growth parameters, was constructed with the FiSAT II program in order to estimate total mortality:

$$Z = F + M$$

where *Z* is the total mortality, *F* is the fishing mortality coefficient and *M* is the natural mortality for the species. *M* was calculated with Pauly's (1980) empirical equation for estimating natural mortality, using a mean habitat temperature of 19^o C according to measurements taken at various sites within the fishing grounds at 30 meter depths (average depth of bottom-longline sets). The exploitation ratio *E* (the proportion of a given population that ultimately dies due to fishing pressure) is included in FiSAT's length-converted catch curve analysis (Gayanillo et al., 1995; Sparre & Venema, 1997).

Recruitment

Monthly recruitment averages, or the addition of new individuals to the local *L. guttatus* population, were computed for July 2007 through June 2008 using FiSAT II's NORMSEP program with the growth parameters established by Elefan I (Beverton & Holt, 1957; Gayanillo et al., 1995). The size and age-at-full recruitment was also defined through this operation. A Kruskal Wallis H test was applied to each quarter (3 month period) to determine whether or not there was a significant increase in recruitment from one quarter to the next.

The sex ratio for *L. guttatus* was additionally calculated from all observed males and females from 2007-2013. A two-proportion z-test was applied to see whether or not the proportion between sexes was significant.

RESULTS

Total length comparison

A total of 10815 individuals of *L. guttatus* were analyzed. The average snapper TL caught with bottom-longlines from July 2007 to October 2013 was 39.9 cm (standard error ± 0.4) varying between yearly averages of 38.0 cm in 2010 and 41.9 cm in 2013. Minimum TLs were between 18.0 cm in 2007 and 2010 and 23.1 cm in 2013. Maximum TLs fell between 60.0 cm in 2011 and 67.0 cm in 2012 (Fig. 2, Table 1). A Mann-Whitney pairwise comparison test showed a significant increase ($P<0.05$) in snapper sizes between 2007 and 2013. There was also a significant decrease ($P<0.05$) in average snapper TLs from 2009 to 2010, and a subsequent significant increase ($P<0.05$) in average snapper TLs from 2010 to 2011. According to the ONI, a strong La Niña event for the Eastern tropical Pacific (characterized by lower than average water temperatures) was recorded in 2010 (NOAA, 2014).

A total of 17.1% of female and 13.7% of male snappers caught with bottom-longlines were immature.

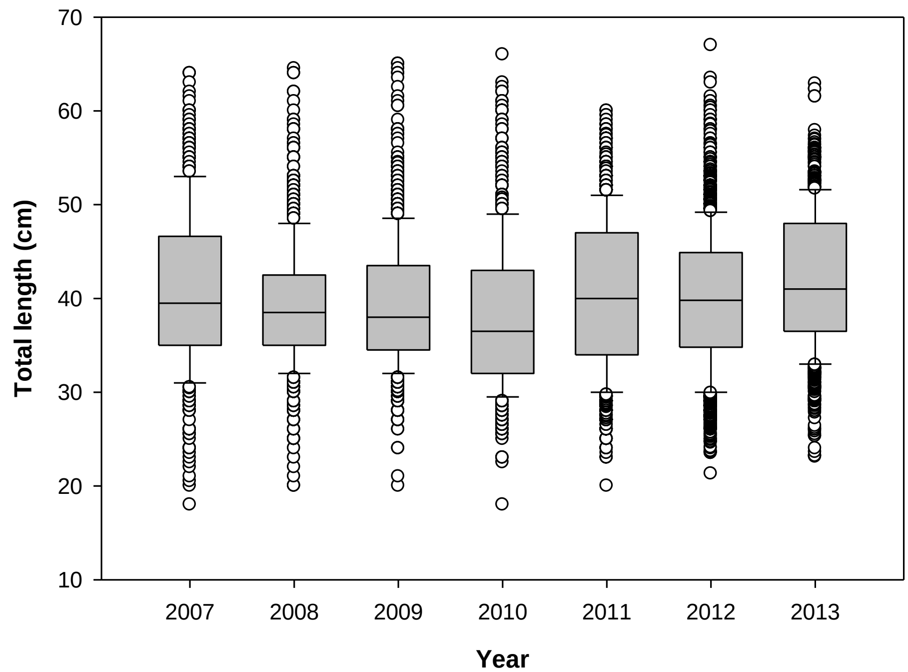

Fig. 2. Box and whiskers plot for *Lutjanus guttatus* TLs over a six-year period between July 2007 and October 2013 in Bejuco, Pacific coast of Costa Rica.

Table 1. Descriptive statistics analysis of *Lutjanus guttatus* TLs for July 2007 through October 2013 in Bejuco, Pacific coast of Costa Rica. Yearly parameters that were measured include TL averages, minimums (Min), the first and third quartiles (Q1, Q3), the median and maximum, standard deviation, standard error, and the number of samples (N).

	2007	2008	2009	2010	2011	2012	2013
Average	40.81	39.22	39.30	38.00	40.47	39.92	41.88
Min	18.00	20.00	20.00	18.00	20.00	21.30	23.10
Q1	35.00	35.00	34.50	32.00	34.00	34.80	36.50
Median	39.50	38.50	38.00	36.50	40.00	39.80	41.00
Q3	46.63	42.50	43.50	43.00	47.00	44.90	48.00
Max	64.00	64.50	65.00	66.00	60.00	67.00	62.90
Standard deviation	8.30	6.48	6.65	7.81	7.74	7.15	7.20
Standard error	0.57	0.39	0.35	0.49	0.32	0.27	0.42
N	838	1133	1438	1012	2383	2856	1155

Weight-length relationship
The calculated weight-length relationship for the species yielded the following parameters: *a*= 0.02 and *b*= 2.79 for pooled sexes (N=4205). Figure 3 presents this relationship for the total data beginning with a TL of 18 cm.

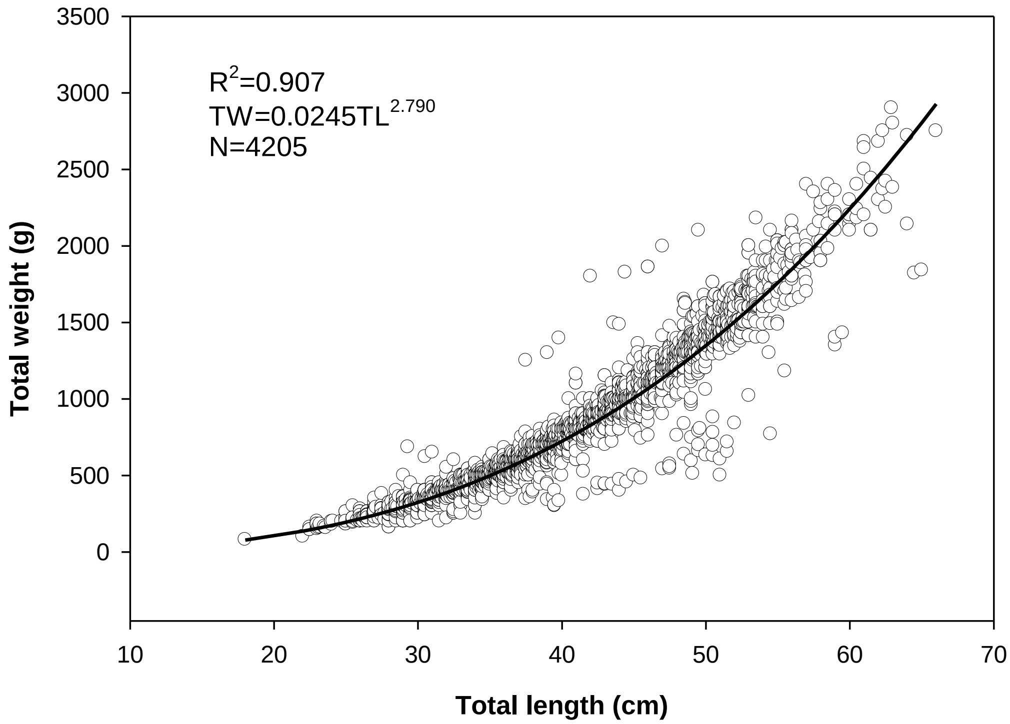

Fig. 3. Weight-length relationship for *Lutjanus guttatus*, Bejuco, Pacific coast of Costa Rica.

Monthly length-frequency analysis in 1 cm class sizes
Total length pooled sex data taken from July 2007 through June 2008 was grouped into 1 cm classes with N values ranging from a maximum monthly sample of 357 individuals (July) to a minimum sample of 16 specimens (December) (Fig. 4). These length distributions revealed that the gear type used selected for individuals beginning at a TL of approximately 20 cm, with full recruitment into the fishery occurring at 39.1 cm TL.

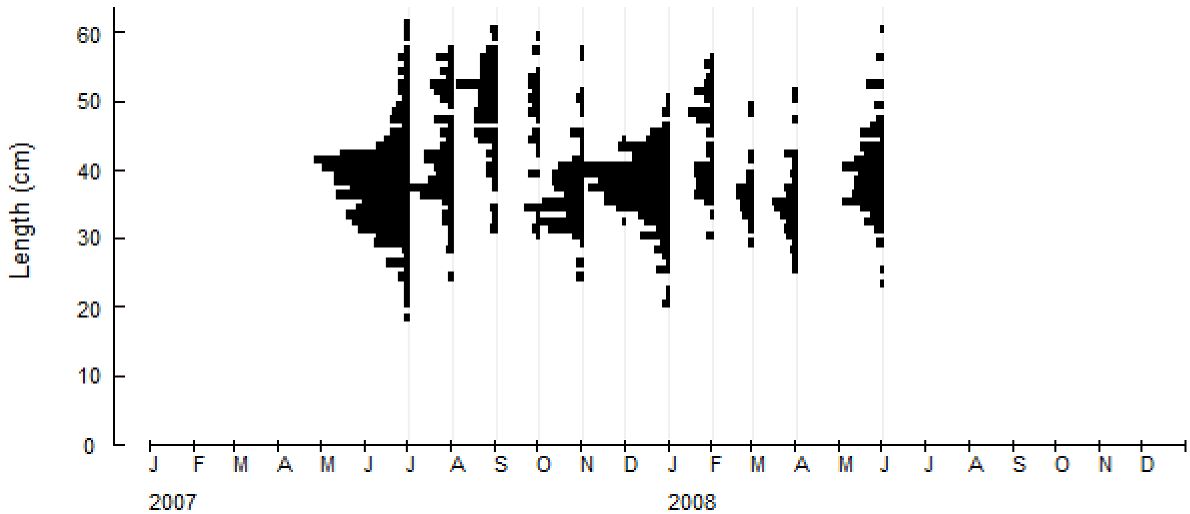

Fig. 4. Grouped length-frequencies in 1 cm classes for *Lutjanus guttatus*, Bejuco, Pacific coast of Costa Rica (from July 2007 through June 2008).

Growth curves

The VBGF resulted in different growth parameters when calculated with Excel/Solver and with FiSAT's Elefan I. Solver determined that L_∞=63.20 cm, K=0.37 and t_0=0 compared with Elefan's results: L_∞=64.58 cm and K=0.21. Figure 5 shows the Bejuco snapper growth curve calculated by Solver and FiSAT II's curve drawn with VBGF parameters derived from Elefan I. Theoretic *L. guttatus* longevity for this study was estimated at 15.6 years with Excel/Solver and 22.4 years with Elefan I.

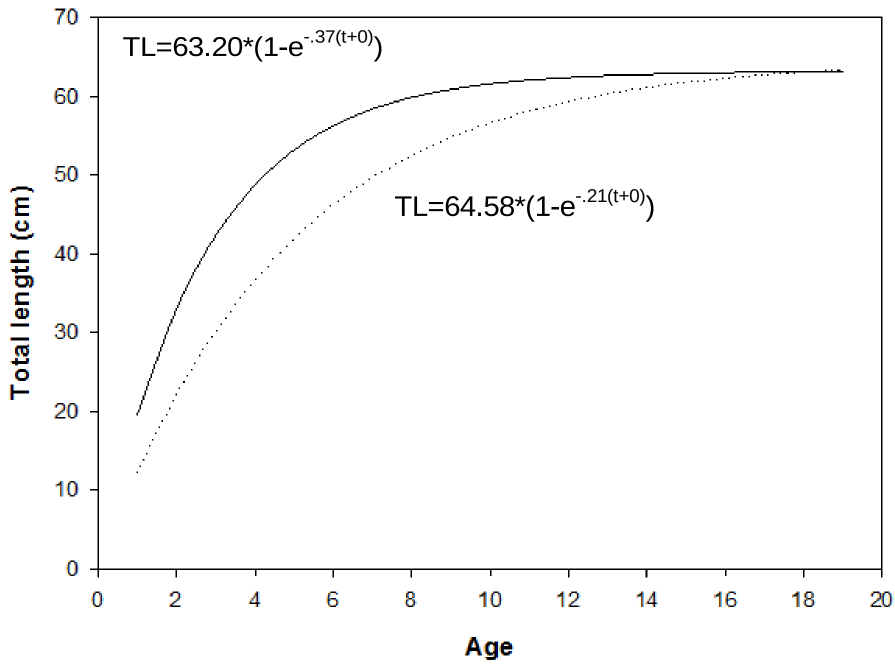

Fig. 5. Excel/Solver (bold line) and Elefan I (dotted line) growth curves for *Lutjanus guttatus* from Bejuco, Pacific coast of Costa Rica, calculated with the von Bertalanffy growth function.

Mortality

Using a value for K=0.21, as determined by Elefan I, the natural mortality (M) was calculated to be 0.43. Fishing mortality (F) was 0.34, yielding a total mortality (Z) of 0.77 and an exploitation ratio (E) of 0.44 (Fig. 6).

Recruitment

Using Elefan I growth parameters, individuals were found to be 4.43 years of age when fully recruited into the fishery (at 39.1 cm TL). Yearly cohort recruitment demonstrated two peaks, one in October (13.9% immature specimens of *L. guttatus*) and one in March (18.1%) (Fig. 6). There was a significantly (Kruskal Wallis H test: $P<0.05$) higher recruitment in quarters one (January-March) and four (October-December) compared with quarters two (April-June) and three (July-September).

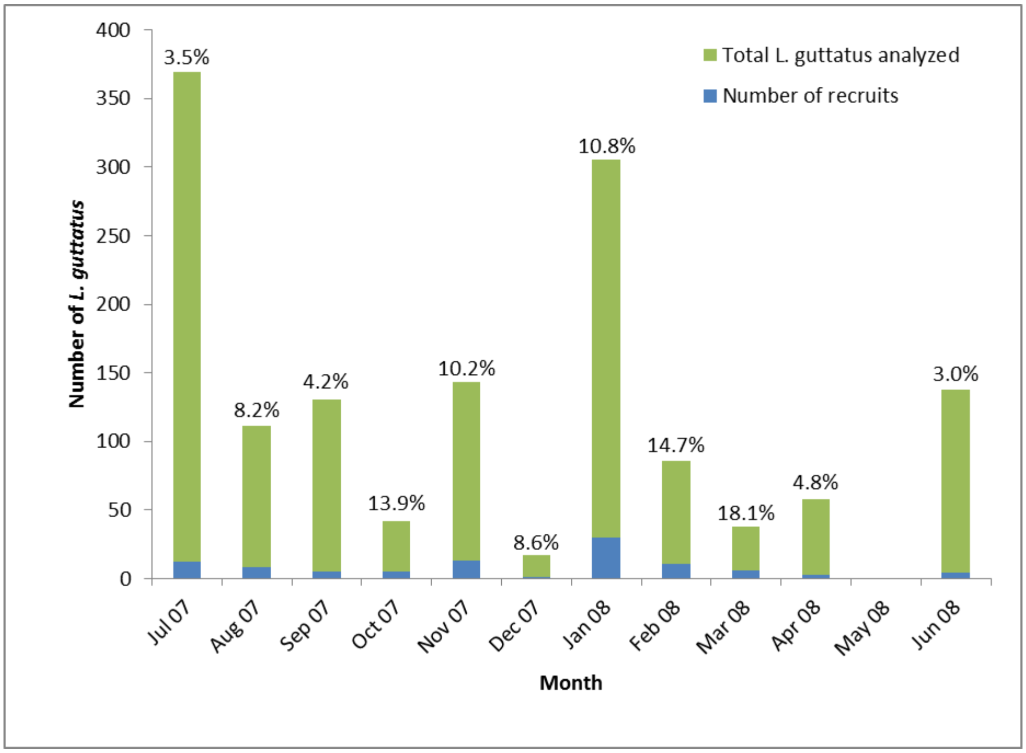

Fig. 6. Total number of *Lutjanus guttatus* analyzed and total number of monthly recruits with percentages, Bejuco, Pacific coast of Costa Rica

The total number of males and females observed during the course of this study was 3410 and 3386, respectively, and the sex ratio was 1:0.99. A two-proportion z-test found no significant difference between the number of males and females.

DISCUSSION

Average snapper size increased significantly in Bejuco from 2007 to 2013 where two multi-use MPAs were established in 2006 and 2010. These MPAs permit bottom-longline use, but do not allow other more unselective techniques including the use of gill nets and shrimp trawls. While legally permitted to fish inside the protected areas, bottom-longline users generally fish between these areas (A. Bystrom, pers. obs.) and could be the beneficiaries of a possible spillover effect occurring from the MPAs. The term spillover refers to the displacement of fish from inside a protected zone to outlying areas in a type of supplemental restocking of fished areas through emigration (Bohnsack, 1990). In fact, Stobart et al. (2009) showed how the spillover effect from 8-16 year old MPAs where fishing activity had ceased, resulted in mean body size increases in a variety of species. Additionally, the mean sizes of emigrating lobsters from a reserve have been shown to be larger than that of those outside the protected area (Goñi, Hilborn, Díaz, Mallol, & Adlerstein, 2010). These studies support the notion that the observed size increase of *L. guttatus* might be related to the establishment of the Bejuco MPAs; however, the time span since the creation of these reserves might still be too short in order to assure such a relation. Continued monitoring of snapper TLs is recommended to better understand variations in snapper stock structure. Marine systems, however, are complex entities and other factors could be influencing snapper size, such as environment-induced factors or genetic variability in life history characteristics, predator/prey relationships, or competitive interactions (Shin, Rochet, Jennings, Field, & Gislason, 2005). Indeed, fishers have mentioned that various species of sharks, once a common bycatch species, have been greatly reduced over the last decade (Bystrom & Cardenas-Valenzuela, in prep.). Therefore, it might be speculated that the decrease in shark populations has caused a higher abundance of snappers because of the absence of these predators.

The strong La Niña event for the Eastern Tropical Pacific in 2010 could have possibly contributed to decreased snapper sizes that year (TL 38.00 cm) as well as the significant variation in average snapper TLs compared with those before the event (2009) and after (2011) it as well. In fact, snappers were smaller in 2010 than they were during any other year of the study. However, according to the National Aeronautics and Space Administration (NASA) (2008), cold-water temperatures associated with a La Niña event increase the growth of living organisms in its area because of a heightened presence of phytoplankton that occurs. This is contradictory to our findings and might mean that the lower average snapper TLs had nothing to do with water temperature.

The literature review of related *L. guttatus* studies from the Pacific coast of Central and South America (including the present study) revealed growth parameters with a L_∞ ranging between 60.0-96.6 cm, K values between 0.13-0.30 and t_0 values to be between 0.03 and -2.66 (Table 2). In studies where the Elefan I routine was applied, L_∞ was in the 60 cm range with a K value between 0.13 and 0.21. The present study in Bejuco, Costa Rica defined an L_∞ of 63.20 and 64.58 (Excel/Solver and Elefan I, respectively), a K value of 0.37 and 0.21 and a t_0 value of 0.0. Of these results, our Bejuco K value of 0.37 (Excel/Solver) is higher than any other published growth rate for this species.

Table. 2. Comparison of population characteristics from *Lutjanus guttatus* populations along the Pacific coast of Central and South America. Information obtained from various studies included the study site and country, snapper sex ratio, TL=total snapper length, in cm or years depending on the study, *Z*=total mortality *E*=exploitation ratio, L_∞=asymptotic length, *K*=growth rate, t_0=size at age 0, *a*/*b*=growth parameters, and the study's reference.

Study site, country	**Sex ratio**	**TL (cm)**	***Z*/*E***	**L_∞**	***K***	**t_0**	***a*/*b***	**Reference**
Gulf of California, Mexico	n.d.	?-48.5	0.35/0.09	66.19	0.13	0.23	n.d.	Amezcua et al. (2006)
Colima, Mexico	1:0.9	20.0-28.0	0.79/n.d.	64.2	0.19	n.d.	n.d.	Cruz-Romero et al. (1996)
Michoacan, Mexico	1:0.96	16.0-62.0	n.d.	96.6	0.22	-0.10	0.01 2.96	Sarabia-Méndez et al. (2010)
Guerrero, Mexico	1:0.96	18.0-60.0	n.d.	n.d.	n.d.	n.d.	n.d.	Arellano-Martínez et al. (2001)
Puerto Quetzal, Guatemala	n.d.	10.4-49.0	n.d.	66.40	0.13	0.03	0.0197 2.8977	Andrade-Rodríguez (2003)
Bejuco, Costa Rica	1:0.99	18.0-66.0	0.77/0.44	63.20 (Solver) 64.58 (Elefan I)	0.37 (Solver) 0.21 (Elefan I)	0.0	0.0245 2.790	Present study
Golfo de Nicoya, Costa Rica	1:0.81 [a]	12.1-60.0 [a]	1.2/0.50[b]	60.0[a]/67 [b]	0.30 [b]	n.d.	n.d.	Rojas (1996b [a]) Vargas (1998-99[b])
Golfo de Nicoya, Costa Rica	1:1	18.0-60.0	n.d.	65.9	0.13	-2.66	0.019 2.82	Soto-Rojas et al. (2008)
Utría National Park, Colombia	1.5:1.0	18.0-56.0	n.d.	n.d.	n.d.	n.d.	0.00001 3.09	Correa-Herrera & Jiménez-Segura (2013)

According to Sparre and Venema (1997), the comparison among growth parameters must be done carefully because they are very sensitive to fishing effort and may vary with the geographic distribution of the population. Our analysis of the published literature from other *L. guttatus* population dynamic studies in the Eastern Tropical Pacific revealed a marked difference in snapper growth rate (Cruz-Romero, Chávez, Espino, & García, 1996; Andrade-Rodríguez, 2003; Amezcua, Soto-Avila, & Green-Ruiz, 2006; Soto-Rojas, Mejía-Arana, Palacios, & Hiramatsu, 2008), presumably because of the aforementioned variations (*K*<21). Also, different methods were used for their calculation, which may have contributed to these interpopulational differences.

In our Bejuco study, Elefan I generated parameters with fish growing at a slower rate (*K*) than those identified by Excel/Solver. When both VBGF curves were compared, the Elefan I curve was shallower (*K*=0.21), therefore favoring slower growth and identifying higher ages at full recruitment and first maturity than the one generated by Solver (*K*=0.37). This difference may be related to the way Elefan I reconstructs data to find the "best" possible growth curve fit for a given species (Pauly & David, 1981). Our Elefan I results regarding growth are in agreement with those reported by Sarabia–Méndez et al. (2010) in their *L. guttatus* study from Michoacan, Mexico (*K*=0.22), as well as by Cruz-Romero et al. (1996) and their snapper growth rate findings (*K*=0.19). At the same time, our Excel/Solver growth rate result (*K*=0.37) was the highest of the identified *L. guttatus* studies in the Eastern Tropical Pacific (Table 2).

Several studies supported their snapper growth analysis with otolith or vertebrae growth ring analysis (Andrade-Rodríguez, 2003; Soto-Rojas et al., 2008). A similar study for the Bejuco snapper stock might provide a source of information that could be used to support or refute this study's identified growth parameters similar to the way they have functioned in Guatemala and Costa Rica (Andrade-Rodríguez, 2003; Soto-Rojas et al., 2008). However, it is important to note that growth rings on these structures are not always clearly defined, often making it necessary to use an alternative method (Wise, 2005), as was done in the Bejuco study where we used two different methods to calculate *L. guttatus* growth. Additionally, our findings are in-line with the previously mentioned studies' Elefan results (taking into account differences in distinct population behavior caused by natural and anthropogenic factors).

There was no significant difference in the number of males and females observed during this study. In all but one of the reviewed studies of *L. guttatus* in the Eastern Tropical Pacific, including the present Bejuco study, yearly sex ratios favored a slightly higher number of males to females (though proportions were not statistically different). The exception to this trend was the Soto-Rojas et al. (2008) study, which determined an equal number of individuals/sex. In a month-to-month comparison of male to female ratios, Correa-Herrera & Jiménez-Segura (2013) found that females of *L. guttatus* in the Utría National Park, Colombia were more abundant in October when spawning was occurring.

The Costa Rican National Fisheries and Aquaculture Institute (INCOPESCA) approved in 2013 a list of minimum size requirements (MSRs) for commonly caught marine species of economic value (La Gaceta, 2013). The list included spotted snappers whose MSR has been set at 34 cm, in accordance with the species size at first maturity reported by Rojas (1996b) for the Gulf of Nicoya. Our data revealed that 17.1% of females and 13.7% of males captured with bottom-longlines in Bejuco were immature. Therefore more selective fishing techniques, or catch and release methods, need to be developed and implemented to minimize the catch of immature *L. guttatus*.

On the other hand, average TLs in Bejuco were higher than those reported for the snapper population in parts of Mexico, Guatemala and Colombia. Correa-Herrera & Jiménez-Segura's (2013) analysis of the handline snapper catch from Utría National Park, Colombia determined that 73.1% of their sample had a TL below 34 cm. The majority of the specimens analyzed were caught with a number 12 J-hook, one that is smaller than the number 7 and 8 J-hook sizes used by Bejuco fishers and therefore targets smaller snappers according to

Mongeon, Granek, & Arauz (2013). The Colombia study did find, however, that snappers reached maturity at a TL=23.5 cm, meaning that 21.6% of the total Utría National Park catch was immature, which is only slightly higher than our values for *L. guttatus* from Pacific Costa Rica. Sarabia-Méndez, Gallardo-Cabello, Espino-Barr, & Anislado-Tolentino (2010) sampled 1579 specimens from the commercial catch at Bufadero Bay, Michoacán, Mexico. The authors determined the average TL of the sample was 32.4 cm, slightly below Rojas' established size for first maturity and well below the Bejuco population's 2013 average TL of 41.9 cm. In Colima, Mexico Cruz-Romero et al. (1996) found that 7% of the *L. guttatus* catch was immature, though their sample contained specimens with TLs between 20-28 cm and the study reported first maturity occurring at 18 cm. Andrade-Rodríguez (2003) observed smaller specimens (between 10.4 cm and 49.0 cm) in Puerto Quetzal, Guatemala obtained from both the artisanal bottom-longline and shrimp trawl catches, further demonstrating how TL frequencies for snapper specimens varied according to collection methods. Because of the economic importance of the spotted rose snapper to artisanal fishers along the Pacific coast of Central and South America, communities whose fishers catch high percentages of juveniles should modify their gear types in order to allow populations of this fish to recover.

Arellano-Martínez, Rojas-Herrera, García-Domínguez, Ceballos-Vázquez, & Villalejo-Fuerte (2001) in Guerrero, Pacific coast of Mexico, used the most similar sample collection methods to the ones used by us in Bejuco where they caught *L. guttatus* specimens with number 6, 7, and 8 J-hooks at depths between 10 and 30 m. However, 85.4% of the 659 specimens analyzed by them were smaller than 34.0 cm. Unfortunately, Arellano-Martínez et al. (2001) did not indicate lengths at first maturity for the local population; however, the following argument might be considered when explaining these difference to our data: bottom-longline use (with 6, 7, and 8 J-hooks) that selects for snappers below 34 cm is an indication that larger individuals may have been overfished, unlike in Bejuco where nearly 84% of specimens were 34 cm or larger. Because indicators of overfishing include a negative change in the size of fish (Dapp. Arauz, Spotila, & O´Connor, 2013) and size/age declines at first maturity (Borisov, 1979) to name a few, lower average TLs for snappers from the Guerrero stock, as compared with those from the Bejuco and Gulf of Nicoya populations, might be associated with higher fishing pressures in this area.

Recruitment of individuals into the bottom-longline fishery demonstrated two yearly peaks (March and October), corroborating tendencies of year-round spawning fish species that demonstrate distinctive periods of heightened activity (Grimes, 1987). These peaks are in accordance with results of previous studies on *L. guttatus* in the Gulf of Nicoya where (1) Soto-Rojas et al. (2008) reported the highest gonadosomatic index occurring in March and September, and (2) Rojas (1996b) mentioned peaks of recruitment for April and October. *Lutjanus guttatus* populations in other parts of the Eastern Tropical Pacific behave in similar ways with spawning peaks in June and October in Colombian waters (Correa-Herrera & Jiménez-Segura, 2013). In the southern Atlantic, Freitas, de Moura, Francini-Filho, & Minte-Vera (2011) found that spawning in *L. synagris, L. jocu,* and *L. analis* exhibited two peaks of reproductive activity, the more intense of which between September and October and the other peak between February and March. In addition, Gutiérrez (1990) determined that *L. peru* recruitment along Costa Rica's Pacific coast was related to two spawning events per year, the first in May and a more intense one in September-October.

Regarding mortality, Cushing (1968) and Gulland (1971) defined a suitable exploitation ratio (*E*) as one between 0.31-0.50. The *E* for the Bejuco artisanal snapper fishery was 0.44, indicating an acceptable level of species exploitation level, although at the high end of the range. The fishing mortality *F* in the Bejuco artisanal snapper fishery was 0.34. The product of *F* and *M* (0.43) values gave a total mortality (*Z*) of 0.77. These mortality-exploitation values were considerably lower than those of Vargas' (1998-99) Gulf of Nicoya study (1.2 and 0.50 values for *Z* and *E*, respectively), where the snapper stock is estimated to be at the uppermost limit of suitable exploitation (Vargas, 1998-99). Other available mortality values for *L. guttatus* from the Gulf of California's stock (Amezcua et al., 2006) identify *Z* and *E* values of 0.35 and 0.09, respectively – considerably lower than the Bejuco results. Cruz-Romero et al. (1996) reported a Z=0.79 in Colima, Mexico (*E* was not defined), a similar total mortality to that of the Bejuco snapper stock. For comparison, Marriott (2005) found that *L. bohar* of the Great Barrier Reef, Australia had a *Z*=0.46. Likewise, *L. malabaricus* and *L. erythropterus* in artisanal line fisheries in Bali, Indonesia showed a Z=0.55 and 0.59, respectively (Fry & Milton, 2009).

Rising snapper TLs, an established MPA system, and an acceptable exploitation ratio suggest that the *L. guttatus* population in Bejuco is being exploited at a sustainable rate by bottom-longline fishers. Average snapper TLs in this study were also higher than those established for all reviewed studies of snapper stocks in the Eastern Tropical Pacific, and the percent of specimens below Rojas's (1996b) established length at first maturity was lower in Bejuco than anywhere else in the region (though other lengths a first maturity have been identified). Continued monitoring and data collection is, however, recommended in order to understand long-term snapper population trends and tendencies. In addition, an analysis of the Bejuco *L. guttatus* stock's length at first maturity would be useful in order to compare the fishing pressure exerted on this population with that on others in the Eastern Tropical Pacific.

CONCLUSIONS

With the possibility of climate change factors and increasing fishing pressure contributing to the reduced productivity of tropical, coastal ecosystem and the gradual displacement of fish stocks to colder waters (OECD, 2010), understanding the population dynamics of commercially exploited fish species now more than ever plays an important role in the management of the fishing industry (Caddy, 1989; Sparre & Venema, 1997; Jackson et al., 2001; Seijo et al., 2004). Because small-scale fishers face an uncertain future, population dynamics of the economically important *L. guttatus* stock in Bejuco, Costa Rica has been compared to findings from other populations of *L. guttatus* in Costa Rica and the Eastern Tropical Pacific. Such information is important to assess how the stock might be responding to management decisions, and how to more effectively develop this fishery in the future.

Since time lags occur between the onset of overfishing and noticeable changes in the target stock's population dynamics (Shin et al., 2005), the true impacts that bottom-longlines have on the Bejuco spotted snapper stock may not be clear for several years to come. For this reason, continued monitoring of this fishery is recommended. Because both legal and illegal shrimp trawling and gillnet use occur within the bottom-longline fishing grounds (A. Bystrom, pers. obs.), data analysis of these fisheries' catch is crucial for a more complete understanding of the *L. guttatus* stock and the combined industries' ecosystem impacts. Along these lines, a multivariate analysis of the entire bottom-longline catch (including bycatch species), as well as of the other fisheries operating in the area, would offer much needed information pertaining to the combined impacts that coastal fisheries are having on resource resilience and fisher subsistence in Bejuco.

While more data collection and analysis should be done to better understand the fishery's impacts on its target species, we believe the data collection and analysis methods implemented by researchers in this study will serve as a base for management initiatives for the Bejuco bottom-longline snapper fishery. What is more, the continued assemblage of catch data from not only the longline fleet but all fisheries that target snappers in Bejuco will allow for a more complete analysis of the effectiveness of the area's MPAs, which in turn could contribute to a replicable coastal management model for use in other areas of the country and region.

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CAPÍTULO II

Catch composition and selectivity of the bottom-longline spotted rose snapper *Lutjanus guttatus* (Steindachner, 1869) fishery at the northern Pacific coast of Costa Rica, Central America

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Abstract
The bycatch and subsequent discard of non-target organisms by the world's fisheries has led to negative impacts on catch yields, fisher income, and marine ecosystem functions. Globally, small-scale fisheries discard an average of 8% of their total catch, though individual gear selectivity varies greatly within this sector. In this study, we analyzed seven years of bycatch data recorded from the Bejuco bottom-longline artisanal snapper (*Lutjanus guttatus*) fishery at Costa Rica's northern Pacific coast from July 2007 to October 2013 in order to determine its catch composition, as well as bycatch and discard rates. *L. guttatus* composed 51.5% of the fishery's total catch. This figure was higher than the percentages of target species catch from all other bottom-longline published studies that we reviewed. Much of this fishery's bycatch (48.5%) is not commercialized or consumed locally, meaning that an estimated 10-20% of the total catch is discarded, a ratio that is higher than the global small-scale fishery average, as well as higher than the global bottom-longline discard average of 7.5%. Anguilliformes from the Ophichthidae, Muraenesocidae, and Muraenidae families accounted for 25.9% of all organisms caught with bottom-longlines. *L. guttatus* and bycatch catch per unit of effort did not significantly change during the research period. A yearly principal components analysis showed an abrupt change in catch composition in 2010, followed by a three year period of little change. This change could have been the result of colder than average surface temperatures in the eastern Pacific caused by the La Niña climatic phenomenon that occurred that year. A multidimensional scaling analysis of species site similarity among Bejuco's 10 fishing sites showed homogeneity across all sites that did not exceed depths of 30 meters.

Key words
Bycatch, discards, non-target species, bottom-longline, Costa Rica

INTRODUCTION

The indiscriminant capture and subsequent discard of non-target organisms by the fishing industry leads to overfishing (Alverson, Freeberg, Pope, & Murawski, 1994; Eggert & Greaker, 2009). This incidental mortality of unused or unmanaged non-target species is a threat to the productivity of many marine ecosystems and a subject of fisheries policy and management concern (Davies, Cripps, Nickson, Porter, 2009; Andalecio, 2010). Discards, or the portion of the catch that is unused and thrown away, and bycatch, or the total catch of non-target organisms including all discards, negatively impact long-term fishery yields, fisher income, and marine ecosystem functions (Alverson et al., 1994; Davies et al., 2009; Eggert & Greaker, 2009). In a global context, discards represent anywhere between 27 and 40.4% of global marine catches (Alverson et al., 1994; Kelleher, 2005; Davies et al., 2009). The problem is compounded in heterogeneous, tropical, coastal fisheries where little monitoring of bycatch – and therefore poor knowledge of actual fishery catch totals – exists (FAO, 2003).

Bycatch is often the result of fishing techniques unable to exclusively select for the fishery's target species (Prellezo & Gallastegui, 2008; Davies et al., 2009; Andalecio, 2010). In response to this, more selective fishing practices and the use of bycatch reduction devices (BRDs), and more effective commercialization of bycatch organisms have all been developed in recent years in order to contribute to the reduction of discard totals (Kelleher, 2005; Andalecio, 2010). This reduction in global discards mitigates impacts on endangered and/or protected species and improves ecosystem health and function (FAO, 2003; Pikitch et al., 2004; Kelleher, 2005). Knowledge of fishing practices and the determination of fishing gear selectivity is of high importance to fishery managers concerned with developing harvest strategies and biological reference points (Myers & Hoenig, 1997; Huse, Løkkeborg, & Soldal, 2000).

Because of the use of more selective gear types, small-scale fisheries often have lower discard rates, accounting for an estimated 11% of global averages, than industrial fisheries do (Kelleher, 2005). Nevertheless, selectivity varies greatly within the small-scale sector because of the wide range of gear types used (FAO, 1984). In small-scale fishing communities along the Central American coast, the bottom demersal longline is considered to be one of the most traditional techniques used by artisanal fishers (OSPESCA, 2009). The Food and Agriculture Organization of the United Nations (FAO) considers bottom-longline use in tropical artisanal fisheries to be a less selective method of fishing compared to other small-scale and industrialized techniques, including hand lines, pole and lines, jigs, and trolling lines FAO, 1984).

The use of bottom-longlines by artisanal fishers in Costa Rica occurs within a diversity of near shore habitat. These areas include mangroves, coral and rocky reefs, areas of sub-aquatic vegetation, bays, estuaries, and islands where up to 80 commercially important fish species co-occur (Nielsen-Muñoz & Quesada-Alpízar, 2006; Cortés, 2007; Wehrtmann & Cortés, 2009). One of the most abundant and widespread of these species, occurring in shallow to medium depth subtropical coastal waters stretching from the Gulf of California to Peru, is the spotted rose snapper (*Lutjanus guttatus*) (González et al., 1993; Fischer et al., 1995a; Rojas, 1996; Vargas, 1998-99; Rojo-Vásquez, Arreguín-Sánchez, Godínez-Domínguez, & Ramírez-Rodríguez, 1999; Andrade-Rodríguez, 2003; Chiappa-Carrara, Rojas, & Mascar, 2004; Rojas, Maravilla, & Chicas, 2004). Commercially exploited throughout its range by both small scale and industrialized fleets, *Lutjanus guttatus* is of high economic importance to Central American as well as Mexican coastal fishing communities (Andrade-Rodríguez, 2003; Sarabia-Méndez, Gallardo-Cabello, Espino-Barr, & Anislado-Tolentino, 2010). Moreover, it is one of the most fished species by Costa Rican bottom-longliners (González et al., 1993; Rojas, 1996; Vargas, 1998-99; Rojas et al., 2004).

In Costa Rica the natural state of coastal ecosystems that support the spotted rose snapper's population are increasingly compromised by coastal development, pollution, and the use of trawl nets and other destructive fishing gear types that result in large amounts of bycatch and discards (Rojas, 1996). The impacts that bottom-longlines have on the local snapper stock and surrounding ecosystem, however, is less understood. We studied the Bejuco fishery's catch composition on Costa Rica's northern Pacific coast in order to determine this gear type's level of selectivity in terms of its effectiveness to catch *Lutjanus guttatus*. These findings may contribute to a better understanding of the relation between the level of species exploitation and possible effects that bottom-longline use may have on the future sustainability of the resource both in Costa Rica and throughout Central America and Mexico where similar hook and line gear types are used (Arellano-Martínez, Rojas-Herrera, García-Domínguez, Ceballos-Vázquez, & Villalejo-Fuerte, 2001; Andrade-Rodríguez, 2003).

MATERIALS AND METHODS

Study area and data collection
Fieldwork was carried out in the district of Bejuco on the southwestern Pacific coast of Costa Rica's Nicoya Peninsula. Data were recorded by the Sea Turtle Restoration Program (PRETOMA), a Costa Rican marine biodiversity conservation non-profit organization. PRETOMA researchers accompanied Bejuco bottom-longline spotted rose snapper fishers on 137 fishing trips to ten areas between July 2007 and October 2013 within and in the surrounding waters of the Caletas-Arío and Camaronal multi-use marine protected areas (MPAs) (Fig. 1).

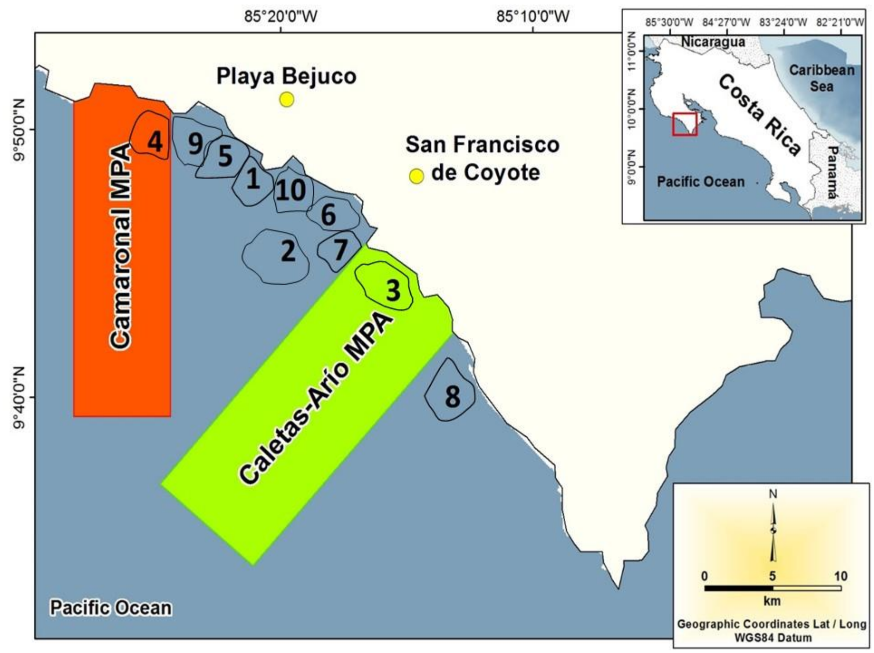

Fig. 1. Location of the 10 fishing areas used by Bejuco bottom-longline snapper fishers from 2007-2013, District of Bejuco, Pacific Costa Rica

Catch composition and CPUE
During each of the fishing trips, the number of captured individuals was recorded and all organisms were identified taxonomically to the lowest level possible according to Fischer et al. (1995a, 1995b) and Fishbase (2014). Organisms were organized into separate species when possible and then counted. Individual organisms were counted and not weighed because of the inaccuracy of weighing fish at night in a small constantly moving craft (5-6 meters). Catch per unit of effort (CPUE) for each of these groups was calculated with the formula: # of individuals / # of fishing trips. Each group's percentage of the total catch was also calculated. All organisms other than the fishery's target species (*Lutjanus guttatus*) were considered to be bycatch.

Yearly CPUEs for 2007-2013 were compiled from all organisms and compared with *L. guttatus* CPUE in a graph. A Kruskal Wallis H test was applied to determine whether or not *L.*

guttatus CPUE and bycatch CPUE significantly changed throughout the study's seven year period.

Retained catch and discards

Exclusively in 2011, all available bills of sale from this fishery, recorded in kilograms, were analyzed to determine the ratio of total fish sold to total bycatch organisms sold. This ratio was then compared to the ratio of the total number of organisms caught to the total number of bycatch organisms caught, recorded during fishing trips carried out during the same time period, to estimate how much of this fishery's bycatch is discarded. In order to calculate this, fish counts and weights had to be compared. While this method is not precise, it allowed for the closest possible estimate of the fishery's discard rate.

Catch multivariate analysis

Of the identified organisms captured, only those with a CPUE > 0.50% were selected for analysis in order to not distort the operations used to construct the matrices with less common species (Clark & Warwick, 2001). The similarity coefficient (S) for species abundance was calculated by standardizing the unequal sampling sizes because fishing effort varied between sites (Hurlbert, 1971). A log transformation was used to allow mid-range and less common organisms to exert influence on the calculation of similarity using the Bray-Curtis coefficient (Bray & Curtis, 1957). A mean similarity dendrogram for hierarchical clustering (using group average linking) for all selected organisms was then constructed based on this Bray-Curtis similarity matrix.

A yearly ordination of the organisms by Principal Components Analysis (PCA) was also calculated. Because of large differences in their catch rates, the data matrix was normalized so that all organisms were of equal importance when determining the principal components. The National Oceanic and Atmospheric Administration's (NOAA) Oceanic Niño Index (ONI) was consulted for changes in equatorial Pacific water temperature caused by El Niño and La Niña events to understand possible causes of any notable differences throughout the seven-year data set (NOAA, 2014). A fishing site ordination using non-metric Multidimensional Scaling (MDS) was applied to the data set to graphically represent the geographic variation of marine fauna assemblages targeted by bottom-longlines within the ten fishing areas.

RESULTS

The observed Bejuco bottom-longline catch was organized into 60 organisms, the majority of which were identified to the species level (Table 1); however, some organisms contained individuals of the same genus, but which could not be identified to the species level. The exception to this was the echinoderms that were arranged under a common phylum.

Lutjanus guttatus captures were 51.5% of the total Bejuco catch. Four of the five most frequently caught bycatch organisms (the exception being the echinoderm phylum) were eels, congers and morays from the Anguilliformes order. The most frequently caught were *Ophichthus* spp. and *Echiophis* spp., from the Ophichthidae (snake eels and worm eels) family, while the third most frequently caught bycatch species, *Cynoponticus coniceps*, belongs to the Muraenesocidae (pike congers) family. The fifth most commonly caught bycatch species, *Gymnothorax equatorialis,* is in the Muraenidae (moray eels) family. These eels, congers and morays accounted for 25.9% of the total bottom-longline catch in Bejuco. With echinoderms making up 3.8% of the total Bejuco catch, the top five organisms comprise 29.7% of all organisms caught on bottom-longlines during this study.

Four other members of the *Lutjanus* genus accounted for 2.9% of the catch. Elasmobranch bycatch (sharks, rays, and skates) comprised 2.8% of all organisms captured

(1.4% sharks and 1.4% rays/skates). The olive ridley sea turtle (*Lepidochelys olivacea*) was the only recorded turtle bycatch species (0.1%).

Table 1. List of organisms including their average CPUEs (individuals/fishing trip) for 2007-2013 and their percentages of the total catch that composed the Bejuco artisanal bottom-longline fishery, Pacific Costa Rica.

Family name	**Species name**	**Average CPUE (2007-2013)**	**% of total catch**
Lutjanidae	*Lutjanus guttatus*	41.9	51.5%
Ophichthidae	*Ophichthus* spp.	9.9	12.2%
Ophichthidae	*Echiophis* spp.	4.3	5.3%
Muraenesocidae	*Cynoponticus coniceps*	4.3	5.3%
	Echinoderms	3.1	3.8%
Muraenidae	*Gymnothorax equatorialis*	2.5	3.1%
Serranidae	*Diplectrum pacificum*	1.9	2.4%
Lutjanidae	*Lutjanus argentiventris*	1.7	2.1%
Sciaenidae	*Micropogonias altipinnis*	1.5	1.9%
Serranidae	*Epinephelus* spp.	1.3	1.5%
Ariidae	*Arius* spp.	0.9	1.0%
Sparidae	*Calamus brachysomus*	0.8	0.9%
Haemulidae	*Haemulon* spp.	0.7	0.9%
Carangidae	*Caranx* spp.	0.6	0.8%
Rhinopteridae	*Rhinoptera* spp.	0.6	0.7%
Sphyrnidae	*Sphyrna lewini*	0.5	0.7%
Triakidae	*Mustelus* spp.	0.5	0.7%
Albulidae	*Albula nemoptera*	0.5	0.6%
Lutjanidae	*Lutjanus peru*	0.4	0.5%
Ophidiidae	*Brotula clarkae*	0.4	0.5%
Malacanthidae	*Caulolatilus affinis*	0.3	0.3%
Myliobatidae	*Aetobatus narinari*	0.3	0.3%
Sciaenidae	*Cynoscion* spp.	0.3	0.3%
Urotrygonidae	*Urotrygon* spp.	0.3	0.3%
Serranidae	*Paralabrax loro*	0.2	0.3%
Sciaenidae	*Umbrina* spp.	0.2	0.3%
Lutjanidae	*Lutjanus colorado*	0.2	0.3%
Carangidae	*Selene* spp.	0.2	0.2%
Haemulidae	*Pomadasys* spp.	0.1	0.2%
Congridae	*Chiloconger labiatus*	0.1	0.1%
Cheloniidae	*Lepidochelys olivacea*	0.1	0.1%
Lutjanidae	*Hoplopagrus guentherii*	0.1	0.1%
Coryphaenidae	*Coryphaena hippurus*	0.1	0.1%

Serranidae	*Alphestes* spp.	0.1	0.1%
Sciaenidae	*Menticirrhus nasus*	0.1	0.1%
Paralichthyidae	*Cyclopsetta* spp.	0.1	0.1%
Sphyraenidae	*Sphyraena ensis*	0.1	0.1%
Carcharhinidae	*Carcharhinus* spp.	<0.1	0.1%
Diodontidae	*Diodon* spp.	<0.1	<0.1
Lobotidae	*Lobotes surinamensis*	<0.1	<0.1
Muraenidae	*Muraena argus*	<0.1	<0.1
Haemulidae	*Haemulopsis* spp.	<0.1	<0.1
Carangidae	*Trachinotus kennedyi*	<0.1	<0.1
Lutjanidae	*Lutjanus novemfaciatus*	<0.1	<0.1
Haemulidae	*Anisotremus interruptus*	<0.1	<0.1
Carcharhinidae	*Nasolamia velox*	<0.1	<0.1
Narcinidae	*Narcine entemedor*	<0.1	<0.1
Synodontidae	*Synodus* sp.	<0.1	<0.1
Rajidae	*Raja* spp.	<0.1	<0.1
Rhinobatidae	*Rhinobatos productus*	<0.1	<0.1
Gymnuridae	*Gymnura marmorata*	<0.1	<0.1
Polynemidae	*Polydactylus* sp.	<0.1	<0.1
Carangidae	*Carangoides otrynter*	<0.1	<0.1
Paralichthyidae	*Syacium latifrons*	<0.1	<0.1
Ginglymostomatidae	*Ginglymostoma cirratum*	<0.1	<0.1
Batrachoididae	*Batrachoides boulengeri*	<0.1	<0.1
Scombridae	*Sarda orientalis*	<0.1	<0.1
Bothidae	*Bothidae* sp.	<0.1	<0.1
Palinuridae	*Palinurus* sp.	<0.1	<0.1
Balistidae	*Balistes* sp.	<0.1	<0.1

A Kruskal Wallis H test determined that snapper and bycatch CPUE variations during the study's seven-year period were not significant ($P>0.05$). *Lutjanus guttatus* and bycatch CPUE were nearly identical during the first three years of the study as each increased by over twenty individuals/fishing trip to reach their highest numbers in 2009 (54.3 individuals of *L. guttatus* and 55.7 bycatch organisms) before declining for the next two years (Fig. 2). *Lutjanus guttatus* and bycatch CPUE diverged in 2012 and 2013 as spotted rose snapper CPUE increased then declined while bycatch CPUE fluctuated little during the last two years of the study. The lowest recorded CPUE for *L. guttatus* was in 2011 (27.7 individuals/fishing trip). Bycatch CPUE was lowest in 2013 (31.3 individuals/fishing trip).

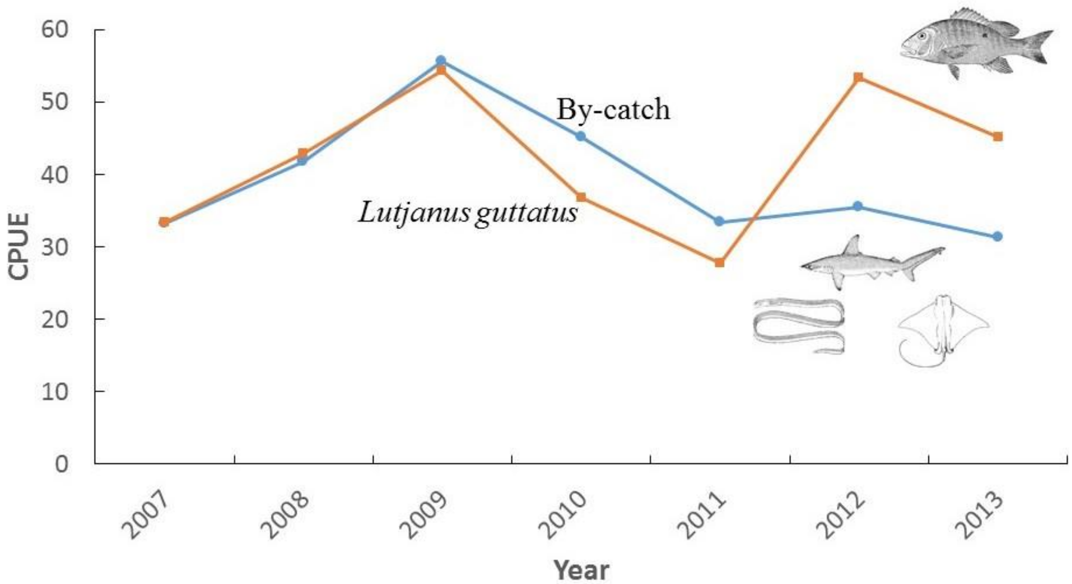

Fig. 2. Comparison of average yearly CPUE (2007-2013) (individuals/fishing trip) for *Lutjanus guttatus* and all other bycatch species in the Bejuco bottom-longline fishery, Pacific Costa Rica. CPUE changes were not significant between years.

According to a sampling of bills of sale from the Bejuco bottom-longline fishery in 2011, 22.3% of the organisms sold to buyers were species other than *L. guttatus*. This figure represents 11.5% of the total catch, meaning 37.0% of bottom-longline bycatch has no market value, or a ratio of one retained individual for every 0.37 individuals that are discarded.

Eighteen organisms had a CPUE over 0.5 and were thus included in the similarity analysis. *Ophichthus* spp. and *L. guttatus* demonstrated the highest similarities (S=50.61) between the 18 analyzed organisms. Other notable organisms with similarities near 50.0 were *Epinephelus* spp. and *Gymnothorax equatorialis* (S=46.89). *Diplectrum pacificum* and echinoderms both share similarities over 40.0 with *L. guttatus* and *Ophichthus* spp.. The two shark organisms, *Sphyrna lewini* and *Mustelus* spp. had a low similarity of 6.0. In terms of the similarities of these sharks with the fishery's target species, *Sphyrna lewini* had an S=25.5 and *Mustelus* spp. an S=14.1. *Rhinoptera* spp. and *L. guttatus* shared a similarity of 21.04. The clustering analysis (Fig. 3) for these similarities provided a visual representation of these assemblages.

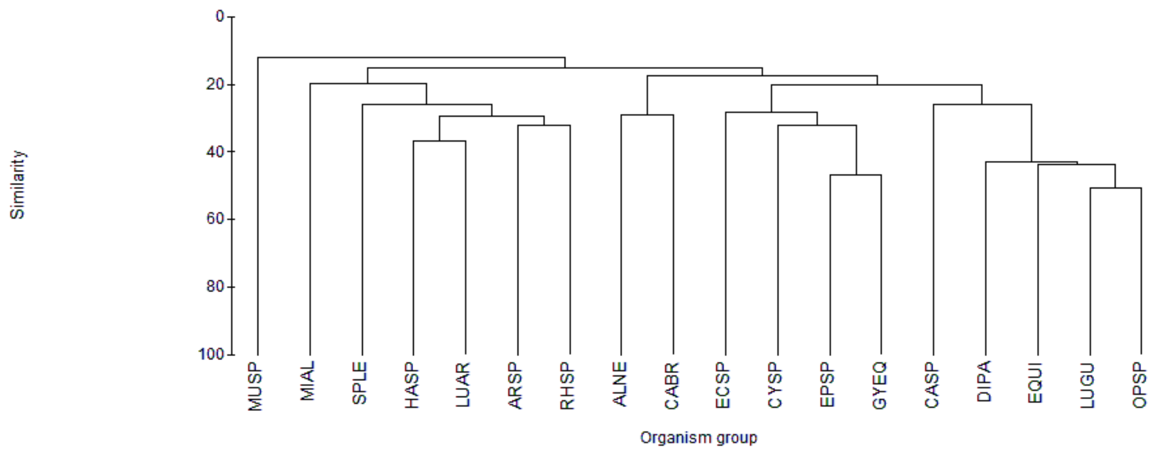

Fig. 3. A standardized mean similarity dendrogram with log transformation for the hierarchical clustering of the 18 organisms with CPUEs over 0.5 in the Bejuco bottom-longline fishery, Pacific Costa Rica. MUSP= *Mustelus* sp., MIAL= *Micropogonias altipinnis*, SPLE= *Sphyrna lewini*, HASP= *Haemulon* sp., LUAR=*Lutjanus argentiventris*, ARSP= *Arius* sp., RHSP= *Rhinoptera* sp., ALNE= *Albula nemoptera*, CABR= *Calamus brachysomus*, ECSP= *Echiophis* sp., CYSP= *Cynoponticus* sp., EPSP= *Epinephelus* sp., GYEQ= *Gymnothorax equatorialis*, CASP= *Carax* sp., DIPA= *Diplectrum pacificum*, EQUI= Equinoderms, LUGU=*Lutjanus guttatus*, OPSP= *Ophichthus* sp.

A two dimensional PCA of the yearly catch composition using the 18 most commonly caught organism assemblages from 2007-2013 (Fig. 4) was obtained from the data in which Principal Components (PC) 1 and 2 accounted for 74.2% of the total variance. Catch composition was shown to change gradually throughout the years of study with the exception of 2010. According to NOAA's ONI, there was a strong La Niña event (characterized by lower than average water temperatures) in the equatorial Pacific during this year. Catch composition was similar in the three years following this natural phenomenon (2011-2013).

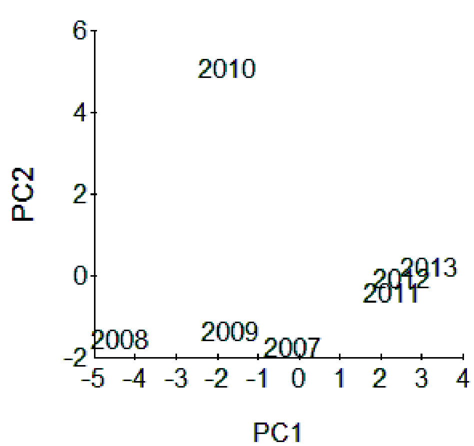

Fig. 4. Principal component analysis (PCA) of organism assemblages for seven consecutive years (2007-2013) in the Bejuco bottom-longline fishery, Pacific Costa Rica

The best 2-d MDS configuration (stress 0.01) for species site similarity from the ten different fishing areas from 2007-2013 (Fig. 5) revealed little distance between all sites with the exception of site 2.

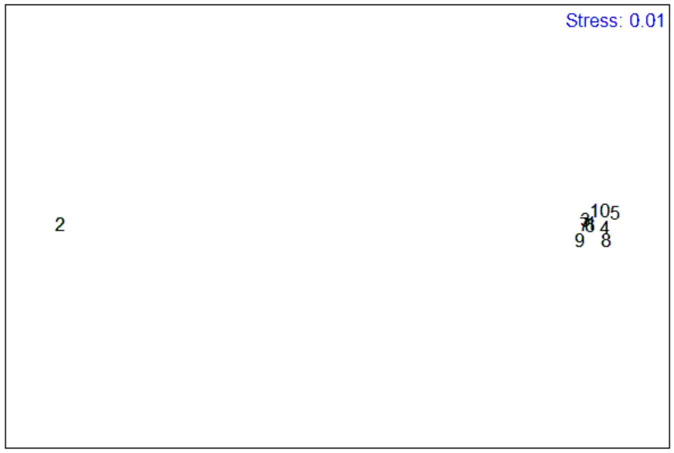

Fig. 5. Multidimensional scaling of species site similarity during 2007-2013 for the Bejuco bottom-longline fishery's ten fishing sites, Pacific Costa Rica

DISCUSSION

The fishery's target species, *L. guttatus*, represented 51.5% of the total number of organisms caught with bottom-longlines in Bejuco during this study. The FAO considers bottom-longlines to be less selective than many other artisanal and industrialized fishing gear types (Alverson et al., 1994) because they do not select for particular species and often result in the capture of large numbers of organisms unintentionally (Hovgård & Lassen, 2000). A review of studies of bottom-longline catch composition in tropical and subtropical coastal waters revealed that no single species represented more than 27% of the total catch, and no *Lutjanus* species exceeds 26% of all captured target or bycatch species (depending on the fishery) (Diplock & Dalzell, 1991; Erzini, Gonçalves, Bentes, Lino, & Ribeiro, 1999; Revolusi, Wibowo, & Sahari, 1999; Beltrano et al., 2004; Mamauag, Aliño, Gonzales, & Deocadez, 2009; Olavoa, Costa, Martins & Ferreira, 2011). The Bejuco *L. guttatus* catch rate is nearly double the target species catch rates reported in these studies, meaning that this fishery is more selective for its target species than other bottom-longline fisheries with published information available.

The capacity of a species' population to withstand fishing mortality depends on the rate of mortality and the life history of the species (Sibly, Brown, & Kodric-Brown, 2012). Regarding the spotted rose snapper's life history strategy, it is of medium length, short-lived, fast growing, and has a relatively high rate of natural mortality (Rojas, 1996; Andrade-Rodríguez, 2003; Amezcua, Soto-Avila, & Green-Ruiz, 2006) allowing for its populations to be more resilient to fishery related mortality than other organisms caught with this gear type (Fujiwara, 2012). According to A. Bystrom et al. (unpubl. data), the species' exploitation ratio for the exploited stock in Bejuco is at an acceptable level and lower than other *L. guttatus* fisheries in Costa Rica.

The only other published exploitation ratio for *L. guttatus* in the region is from the Gulf of California's stock where it was calculated to be considerably lower than the Bejuco results (Amezcua et al., 2006).

Bycatch in this fishery was 48.5% of the total catch and does not regularly include threatened, endangered or protected species. Therefore the fishery's bycatch can be considered moderate according to Lutchman (2014). Bycatch rates have been reported to be around 19% for various bottom-longline fisheries that target multiple target species in the Azores (Pham et al., 2013). Since few, if any, tropical, near shore, *Lutjanus*, bottom-longline, catch composition studies exist, comparing this fishery's catch composition to other similar fisheries is difficult to do. On the other hand, the U.S. Atlantic bottom-longline shark fishery's bycatch is composed of organisms from the following groups: Selachimorpha (90%), Serranidae, Anguilliformes, Batoidea, Invertebrata, Lutjanidae (Morgan et al., 2010). This composition is similar to the Bejuco fishery's catch, although sharks only compose 3% of Bejuco's total catch. The Gulf of Mexico's reef fish fishery's catch composition includes 240 species, the second most captured of which is *Lutjanus campechanus* (Scott-Denton et al., 2011). This list of bycatch species, by comparison, is considerably more extensive than the Bejuco fishery's list of bycatch organisms.

Anguilliformes from the Ophichthidae, Muraenesocidae, and Muraenidae families accounted for over a quarter (25.9%) of all organisms caught with bottom-longlines. While some of these organisms are discarded, *Cynoponticus coniceps* has commercial value and is sold to local buyers. *Ophichthus* spp., while not commercialized directly, are used as bait for portions of reset lines. This practice of using these types of organisms as bait is also observed in the Gulf of Mexico's reef fish bottom-longline fishery (though they only composes 2.5% of this fishery's total catch) (Scott-Denton et al., 2011). Experimental bottom-longlines used in Colombia have been shown to capture more Anguilliformes than any other bycatch species with no commercial value (Gómez et al., 2014), thus corroborating our results of the Bejuco bottom-longline fishery.

Quantifying the impact that bottom-longlines are having on these organisms' population, however, is difficult to assess because their global and regional biological and ecological information, including population status, is scarce (McCosker & Rosenblatt, 1998; Zokan, 2008; Matic-Skoko et al., 2011; Gómez, Caicedo, & Zapata, 2014). Most of the Anguilliforme bycatch organisms in Bejuco, including ophichthid fauna, are wide ranging eastern Pacific species (McCosker & Rosenblatt, 1998). Many of these species live at depths from zero to several hundred meters, spending much of their time concealed inside crevices and alcoves of coral and rocky substrates, or burrowed into loose gravel and sand (McCosker & Rosenblatt, 1998; Matic-Skoko et al., 2011). Bottom-longlines are demersal and remain submerged on the sea floor in suitable Anguilliform habitat for multiple hours at a time, thus facilitating their capture. While many of these organisms tend to be short lived and fast growing (Zokan, 2008), data deficiencies concerning their life histories make it difficult to determine the impact that the bottom-longline fishing effort is having on them locally.

Though significant changes in bottom-longline CPUE were not observed during this study, by-catch CPUE diverged from *L. guttatus* CPUE beginning in 2012 after being similar for the previous five years. Gillnet and coastal shrimp trawl fisheries that result in high incidences of bycatch and exert stress on multiple populations of coastal organisms (Campos, Burgos, & Gamboa, 1984; Alverson et al., 1994) operate in the same fishing grounds that bottom-longliners do. The combined fishing mortality exerted on these organisms by these three fisheries may be negatively impacting the populations of these bycatch organisms, though additional studies are needed to assess the bycatch composition of the three fisheries mentioned above, which are operating in the same fishing area.

Lutjanus guttatus sales represent nearly 80% of the total product sold to district buyers. With such a high dependence on the spotted rose snapper population, any negative changes to its abundance could drastically impact Bejuco fishers' economic wellbeing. Other snapper species including *L. argentiventris* and *L. peru* contributed little to the fishery's total production, thus placing even more reliance by fishers on the *L. guttatus* stock.

Many tropical coastal fisheries lack adequate data and management strategies that govern the capture of bycatch species with little or no economic value (Eggert & Greaker, 2009). This describes the Bejuco artisanal fishery, where a wide variety of marine species with no commercial value are caught during normal fishing activities. Artisanal fisheries are frequently multi-gear with low rates of discard (Batista, Fabré, Malhado, & Ladle, 2014). Globally, discard rates average 8% of the total catch in weight with demersal (bottom) longlines averaging 7.5% (Kelleher, 2005). According to Misund, Kolding, & Fréon (2002), discard rates for many artisanal fisheries are only about 5% of the total catch, while the Gulf of Mexico bottom-longline and vertical line fisheries have a combined 6% discard rate (Scott-Denton et al., 2011). This study's discard ratio of 37% falls at the high end of global averages (Alverson et al., 1994; Davies et al., 2009). This figure, however, contains organisms that are used as bait and/or consumed locally by fishers, their families, and other community members as some species are traded for other goods and services (Bystrom, Naranjo-Madrigal, & Wehrtmann (in prep). *Diplectrum pacificum*, *Cyclopsetta* spp., and *Caranx* spp. are a few examples of "junk" fish (a local reference to organisms with little or no economic value) that are consumed by fishers and other community members. In this regard the Bejuco fishery demonstrates characteristics of a subsistence fishery in the way communities rely on a portion of the fishery's production for self-consumption and therefore food security (Garcia & Rosenberg, 2010). These local uses for many of the fishery's bycatch organisms lower its discard ratio to an estimated 10-20% of the total catch (Bystrom per obs.), a ratio that is still slightly higher than the bottom-longline average according to Kelleher (2005).

The use of different hook sizes in Bejuco's bottom-longline fishery have been shown to increase and decrease the catch rate of non-target species, depending on their size (Mongeon, Graneka, & Arauz, 2013). But, as these authors demonstrated, larger hook sizes also reduced the catch of the fishery's target species, leading Alhem to conclude that the J7/8 hooks currently used by fishers are correctly sized to minimize bycatch rates without overly reducing the total *Lutjanus guttatus* catch. This being the case, the configuration of bottom-longlines used in Bejuco cannot reasonably be modified to reduce this fishery's bycatch rate.

Regarding the reduction of bycatch and discards, the FAO recommends, among other suggestions, the greater utilization of bycatch species for both aquaculture and human consumption, and the adoption of more selective fishing methods (Keller, 2005). Since Mongeon et al. (2013) have already shown the impracticality of developing a more selective bottom-longline in Bejuco, the solution to deducing discards might be to develop new markets and consumption patterns in Costa Rica that promote the sale of previously unused organisms. A reduction in effort could also compensate for higher discards rates. Studies on tropical, continental shelf-trawl fisheries suggested that a 60% decrease in effort is needed to return to optimal resource use (McManus, 1997). While we have already shown in this study how discard rates for trawl fisheries are higher than the Bejuco bottom-longline fishery's rate, a reduction in effort might positively impact its long-term sustainability. Understanding Bejuco's yearly production rate would help to determine if the current bycatch and target species catch is sustainable.

A multivariate analysis of the 18 most commonly caught organisms was performed in order to consolidate the considerable amount of bycatch information collected over the range of seven years from ten fishing sites and their habitats. The analysis discerned four principal assemblages. The hierarchical clustering for Bejuco's bottom-longline catch showed the highest levels of similarity to be between snappers, snake eels, echinoderms, and perch (*Diplectrum pacificum*). Because Costa Rica's national waters are home to an estimated 7,000 marine species (3.5% of the world's marine diversity) (Wehrtmann & Cortés, 2009) it comes to reason that Bejuco's coastal areas would demonstrate fish assemblages of multiple species of both commercial and noncommercial value. While it is generally accepted that ecological communities are variable (Dayton & Tegner, 1984; Kotliar & Wiens, 1990), our study gives insight into how snake eel, echinoderm, and perch habitat possibly overlap with that of *Lutjanus guttatus*. García, Duarte & von Schiller (1998) reported the highest levels of similarity between *Lutjanus analis* (31.8% of the catch) and *Calamus penna* (19.5% of the catch) for their study in the continental shelf waters in the Colombian Caribbean (sampling gear type: trawl nets). While these species differ from those caught in Bejuco, *Calamus brachysomus* and *Lutjanus* spp. were among the 18 organisms with the highest percentages of the total catch and *Calamus brachysomus*'s similarity with *Lutjanus argentiventris* was 21.9. García et al. (1998) did not report any anguilliform catch, possibly because of the trawl nets they used. Bouchon-Navaro, Bouchon, Louis & Legendre (2005) reported that community composition variation was influenced more by habitat type, rather than by depth. A habitat characterization within the Bejuco fishing grounds could determine if the assemblages identified from the bottom-longline catch composition vary in this same regard.

The yearly species PCA analysis showed an abrupt change in 2010 catch composition as compared to the other years of this study, followed by a three-year period of little change (2011-2013). The year 2010 was characterized by colder than average surface temperatures in the eastern Pacific caused by the La Niña (NOAA, 2014). The climatic phenomenon could have impacted the presence and relationships between coastal marine organisms commonly caught with bottom-longlines. Among the factors that control organism distribution and abundance is their individual use of available resources (Ross, 1986). During the La Niña phenomenon, upwelling events, and therefore the presence of colder water, sometimes increase and promote the growth of living organisms because of heightened primary productivity due to higher amounts of nutrients (Garcia, Vieira, & Winemiller, 2001; Glantz, 2002; NASA, 2008; Thatje, Heilmayer, & Laudien, 2008). This supports the correlation presented by Rowe (1971) between deeper water biomass and primary productivity of the overlying water column, as well as the belief that areas of high species richness are associated with areas of high phytoplankton concentrations (McClatchie et al., 1997; Floeter et al., 2001; Garcia et al., 2001). Additional climatic fluctuations caused by the El Niño Southern Oscillation (ENSO), including increased rainfall amounts, have been shown by Meynecke, Grubert, Arthur, Boston, & Lee (2012) to cause an increase in the Northern Territory of Australia's *Scylla serrata* (giant mud crab) catch, as well as the diversity of fish bycatch along the Colombian Pacific coast (Zapata-Padilla, 2002). At the same time, Gaymer, Palma, Vega, Monaco, & Henríquez (2010) and Riascos, Heilmayer, & Laudien (2008) showed how physical processes associated by the ENSO cause decreased recruitment and abundance of certain benthic organisms in Chile and an increased mortality of the tropical bivalve *Cardita affinis* along the Colombian Pacific coast. Since no sampling changes were made during the course of the Bejuco study, the catch composition changes experienced in 2010 and the following three-year similarity are not due to researcher influence. Rather, they may reflect a dynamic coastal ecosystem constantly impacted by natural disturbances, and additional studies are needed to better understand the relation between climatic events (e.g., La Niña, ENSO etc.) and catches of the artisanal fisheries in Bejuco and adjacent areas.

The MDS visualization of the level of similarity of species caught at the ten fishing sites reflected homogeneity across the entire fishing grounds with the exception of site 2 (Fig. 1), located further offshore and in deeper water than the maximum 30 m depths where snappers are commonly fished (Fisher et al., 1995b). However, Bouchon-Navaro et al. (2005) found community composition variation to be most dependent on habitat type rather than depth. This could mean that the habitat type at site 2 is different from the rest of the Bejuco fishing locations. Bejuco bottom-longliners use this site to fish for groupers (*Epinephelus* spp.) and it is therefore the only site where *L. guttatus* is not the target species. The remaining sites are remarkably similar and their location whether within, alongside, or between the area's two MPAs makes little difference in the similarity of species caught with bottom-longlines. *Lutjanus guttatus* is an inshore reef-dwelling species found over hard bottoms (Allen, 1985), and the nine nearshore areas throughout the Bejuco bottom-longline fishing grounds all appear to be located within habitat types that support this species' assemblages.

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CAPÍTULO III

Use of fisher knowledge to determine socio-ecological tendencies in the Bejuco small-scale bottom-longline fishery, Guanacaste, Costa Rica

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Abstract
The bottom demersal longline is considered to be one of the most traditional techniques used by artisanal fishers throughout Central America. Despite the widespread use of this fishing technique, there is a lack of information needed to effectively manage these fishers' activities. In this study we used quantitative and qualitative data collection methods of fisher ecological knowledge (FEK) to determine socio-ecological tendencies of bottom-longline snapper (*Lutjanus guttatus*) fishers in the district of Bejuco, Pacific coast of Costa Rica. We applied a survey to the entire population of bottom-longline users (n=49) to collect information about fisher socio-economic and ecological tendencies. Two focus groups and individual semi-structured interviews were used to collect additional information and to clarify fisher survey responses. Bejuco's bottom-longline fishers demonstrated typical characteristics of the country's poor, rural populations. While content with their quality of life in their communities, respondents recognized that their earnings have been reduced over the last few years, causing them to be unable to cover all of their household expenses. They also believe that bottom-longlines are an effective way to catch snappers. Fishers view their activity as sustainable, though they had difficulties defining this term. They identified that a shrimp trawl fishery's spatio-temporal allocation of effort within the Bejuco fishing grounds is the cause of overexploitation of the local snapper resource. Nearly all fishers said they captured fewer snappers today than they did in the past, and all respondents felt it has to fish longer today to catch the same amount of fish than it did a decade before. As a way of mitigating these economic concerns, some fishers have switched gear types from lines to gillnets, thereby creating a multi-specific fishery aimed at improving its profitability. Some management plan recommendations were made based on the FEK collected in this study.

Key words
Fisher ecological knowledge, historical reconstruction, socioeconomic, small-scale fisheries

INTRODUCTION

Members of communities whose lifestyles are closely linked to the state of the area's natural resources tend to have high levels of knowledge regarding their environmental interactions (Berkes & Folke, 2002; Johannes & Neis, 2007; Nenadovic, Johnson, & Wilson, 2012). This fisher ecological knowledge (FEK) is normally transmitted orally among fishers, their family members, and other personnel in this sector (Neis et al., 1999; Berks, 2003; Johannes & Neis, 2007). While much of this knowledge is based on the bio-physical environment within which fishers interact, it is not confined to this topic (Pauly, 1995). FEK's scope not only includes fisher's knowledge of natural areas, but it also consists of historical and social information about the fishery and its market stakeholders (Pauly, 1995; Neis et al., 1999; Murray, Neis, & Johnson, 2006).

In the absence of sufficient scientific information, FEK, also referred to as local ecological knowledge (LEK), has been used to support and justify fishery management decision making (Fischer, 2000; Gosse, Wroblewski, & Neis, 2001; Berkes & Folke, 2002; Murray et al., 2006; Lutz & Neis, 2008; Nenadovic et al., 2012). The prevalence of this information has led to its increased application during the management decision making process (Neis & Felt, 2000; Apostle, McCay, & Mikalsen, 2002), thereby reducing fishery managers' dependence on traditional catch data to design models of past ecosystems (Pitcher, 2001). More specifically, FEK relating to the spatial and temporal components of multi-specific fisheries has been proposed for use during the development of governance mechanisms designed to manage multiple fishery activities within complex marine environments (Moreno-Báez et al., 2012). Considering that most fisheries around the world are considered to be data-deficient and lack FEK incorporation strategies into their management regimes (Honey et al., 2010), the need to develop and implement assessment techniques applicable to more of the world's fisheries, including tropical, small-scale, coastal fisheries, is growing in importance (Johannes, 1998; Prince, 2010). This being the case, the acquisition of FEK, as well as other types of qualitative information for the design and implementation of management plans, should be considered to be an important part of data-poor fishery development strategies (Mackinson & Nottestad, 1998; Astles et al., 2006).

Similarly, the ability to reconstruct the history of fish stocks and ecosystems in the absence of recorded data is a valuable tool that allows managers to assess the cumulative impacts of a fishery as well as potentially improve its management in the future (Zeller, Booth, Craig, & Pauly, 2006). Furthermore, our understanding of the direct and indirect cultural value of these resources is increased when we are able to piece together their historic extraction trends (Zeller et al., 2006). To this end the use of FEK aids in this historical reconstruction and ultimately our understanding of the socio-ecological connection that exists between fishers and traditionally fished species (Murray et al., 2006).

At the same time, effective fishery management requires an interdisciplinary approach that includes socio-economic studies, including the resource users' demographic information (Chuenpagdee et al., 2005; Gill, McConney, & Mahon, 2007; Gasalla, Rodríguez, Duarte, & Sumaila, 2010). This deeper understanding of the industry's social and economic components further supports management recommendations and overall fishery development efforts (Christensen, 2010). Despite its importance, the addition of socio-economic information gathering tools to develop resource management strategies is not widely used (Salas, Chuenpagdee, Seijo, & Charles, 2007; Leite & Gasalla, 2013). This limited presence of the aforementioned management tactics has had a deleterious impact on fisher livelihoods (Allison & Ellis, 2001; Maunder et al., 2006). One such example of this is the small-scale fishing (SSF) sector in tropical developing countries, including those in Latin America and the Caribbean (LAC) where research in the region is for the most part biological and/or ecological in nature and fails to cover socio-economic, policy, and governance issues (Andrew et al., 2007; Salas et al., 2007). The notion that socio-economic aspects are rarely considered during the assessment of LAC SSFs is further supported by Herrera-Ulloa, Villalobos-Chacón, Palacios-Villegas, Viquez-Portuguéz, & Oro-Marcos (2011) who noted that demographic and other socio-economic statistics of the Costa Rican population employed in SSFs are deficient and/or otherwise limited in scope, leading to knowledge gaps and assessment challenges.

Along Costa Rica's Pacific and Caribbean coasts, SSFs are community-based and considered to be an expression of local culture (Chang & del Río, 2004). Due to a steady decline in coastal fishery productivity since 2001 (Araya et al., 2007), the industry now faces a growing number of development challenges common to tropical SSFs the world over. These challenges include overexploitation of coastal resources, competition and other conflicts arising from fleet interactions (small-scale, industrial and recreational), and a lack of infrastructure that exacerbates postharvest and chain of custody problems (Salas et al., 2007). What is more, a general lack of the information needed to strike a balance between aquatic resource protection measures and socio-economic development opportunities has left this sector without the means to effectively manage its activities (Quesada-Alpízar, 2004; Alvarado, Herrera, Corrales, Asch, & Paaby, 2010; Alvarado, Cortés, Esquivel, & Salas, 2012). For this reason, the present study collected FEK to determine socio-ecological tendencies among members of Costa Rica's SSF sector. The results of this study can be used to aid development decisions and strategies that ultimately improve the management of the socio-ecological systems within which this sector operates both in Costa Rica as well as the greater LAC region.

MATERIALS AND METHODS

Study area

The present study of FEK among SSF fishers was carried out from May-November 2013 in the communities of Pueblo Nuevo and San Francisco de Coyote, located along the southwestern Nicoya Peninsula, Pacific coast of Costa Rica (Fig. 1).

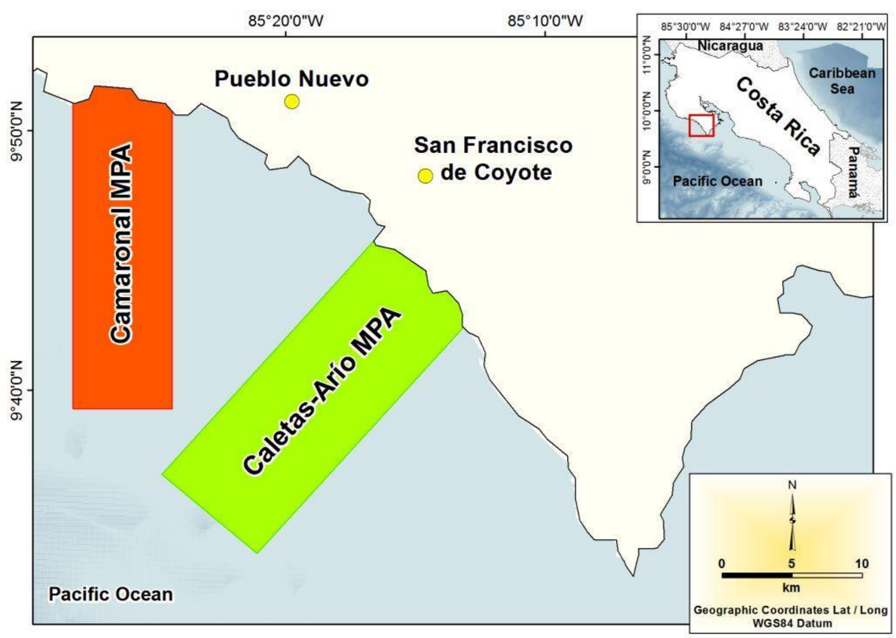

Fig. 1. Site map of the study area including the Camaronal and Caletas-Arío marine protected areas (MPAs), Nicoya Peninsula, Pacific coast of Costa Rica.

While Bejuco fishers use a variety of gear types to fish, the most common of these is the bottom-longline. Bottom-longline users focus their fishing activities on the spotted rose snapper, *Lutjanus guttatus* (Steindachner, 1869), one of the most commonly caught and economically important SFF species not only along Costa Rica's Pacific coast, but throughout Central America (González et al., 1993; Rojas, 1996; Vargas, 1998-99; Andrade-Rodríguez, 2003; Rojas, Maravilla, & Chicas, 2004).

Data collection

A survey was developed and applied in person to the entire bottom-longline user population of Bejuco (n=49) (see appendix I). This population was chosen because it represents the majority of the active small-scale fishers in the district. The survey contained 46 questions, of which 14 were used to construct a social-demographic profile of the population. This survey also contained a test designed to collect FEK. The test was divided into two themes: socio-economic tendencies and ecological tendencies. The socio-economic tendencies theme had two variables: fisher socio-economic situation and lifestyle perceptions, and bottom-longline use. The ecological tendencies theme had two variables as well: fishery sustainability and historical reconstruction of the fishery. Each variable consisted of multiple questions (items). Fisher responses to these items were measured using a Likert scale (Likert, 1932). The scale contained four categories (0-3) where 0 was highly disagreeing, 1 was disagreeing, 2 was agreeing, and 3 was highly agreeing. Items poised as negative questions were re-coded during their analysis. Fisher responses to the individual items for each variable were grouped together and a Chi-square goodness-of-fit test was applied to determine if fisher responses differed significantly from a random distribution of answers.

A pre-test (May, 2013) of the survey was applied to five fishers. Questions that were confusing to fishers were rewritten and the final survey was applied to Bejuco's population of bottom-longline fishers.

A second phase of data collection using the triangulation method was incorporated into the study (Webb, Campbell, Schwartz, & Sechrest, 1966) in order to obtain more FEK about specific research topics. Information for this method was collected through two focus groups: the first regarding the fishers' economic situation and quality of life in their communities, and the second on fisher views and knowledge of sustainability issues. Participants in these groups included fishers and other members of the community who contributed to the overall maintenance of the fishery (untangling, repairing, and baiting bottom-longlines). A total of five fishers and two community members (n=7) participated in the first focus group. The duration of this conversation was one hour. Four fishers and one community member (n=5) participated in the second group; the duration of this conversation was 45 minutes.

Individual semi-structured interviews were applied to Bejuco's three snapper buyers in order to clarify fisher responses on specific aspects of their activities. These individuals were asked to expound on certain subjects where fisher responses were divided. These topics included knowledge of the Bejuco fishery's total production, changes in snapper sizes, snapper and bycatch seasonality, the market price of snappers, and alternative gear type use.

The applied survey also contained 11 questions not associated with its four variables or social demographic profile. These questions were open-ended and were designed to allow researchers to collect additional qualitative information about fisher knowledge and experiences. The results of the focus groups, semi-structured interviews, and open-ended survey questions were transcribed, and a search for keywords and ideas was performed in order to determine common fisher points of view and idea trends. These points of view were then used to more thoroughly explore and interpret the four variables' results.

RESULTS

During the second half of 2013, 55.1% of the population of Bejuco bottom-longline fishers were members of a formal fishing association, while the remaining 44.9% of the population fished independently (Table 1). When asked about the benefits of being an association member, respondents cited small financial handouts and assistance with applying for fishing licenses with Costa Rica's Fisheries and Aquaculture Institute (INCOPESCA), the country's national fisheries regulating organization, as the main reasons to be a member of an association.

Table 1. Social-demographic profile of the population of bottom-longline fishers (n=49) in the district of Bejuco, Pacific coast of Costa Rica.

Category	**Number of Bejuco bottom-longline fishers**	**% of Bejuco bottom-longline fishers**
	Association members	
Member of an association	27	55.1
Independent fisher	22	44.9
	Education	
Partial or completed grade school	37	75.6
Partial or completed high school	6	12.3
No formal education	5	10.2
Partial college	1	2.0
	Marital status	
Single	24	49.0
Living with partner	21	42.9
Married	4	8.2
	Housing	
Own	31	63.3
Borrowed	9	18.4
Rent	5	10.2
Squatter	4	8.2
	Construction material	
Cement	18	36.7
Wood	17	34.7
Cement/wood combination	12	24.5
Metal	2	4.1
	Housing characteristics and personal effects	
Electricity	48	98.0
City water	46	93.9
Telephone or cell phone	46	93.9

Electric or gas stove	45	91.8
Flush toilet	43	87.8
Refrigerator	41	83.7
Color television	41	83.7
Washing machine	38	77.6
Cable or satellite service	18	36.7
Computer	6	12.2
Fisher age		
<20 years	3	6.1
20-29 years	9	18.4
30-39 years	17	34.7
40-49 years	14	28.6
50-59 years	6	12.2

In terms of the amount of formal schooling completed by these fishers, the majority of the respondents has either a grade school education or never finished grade school (Table 1). Fishers do not often enter into legal marriages with their spouses, although nearly half of the fishers live with a partner (Table 1). All survey respondents except one were male.

An average of five people live in each fisher household with two individuals per bedroom. With respect to these households, most are homeowners, though others do live in a variety of different housing situations (Table 1). The material used to build these homes is generally cement, wood, or a combination of these two materials (Table 1). Regarding these living quarters and fisher personal effects, nearly all homes have basic services including electricity, indoor plumbing and city water. Most fishers and their families have cell phones, televisions, washing machines, refrigerators, and stoves. The majority does not own a computer and does not have cable television or satellite service (Table 1).

The average age of Bejuco bottom-longline fishers is 36.5 years (Table 1), with individuals having fished in the district for an average of 16 years.

The Bejuco bottom-longline population believes that its economic wellbeing has declined during the time it has fished professionally (Table 2). Furthermore, fishers recognize that their earnings have been reduced over the last few years, causing them to be unable to cover all of their household expenses. Because of this trend they do not believe that their families will be economically stable in the future. Despite this negative economic panorama, bottom-longliners feel that they have a good quality of life in their communities and that they will continue to use this same fishing technique in the future.

The p value for grouped fisher responses to all items from the economic situation and earnings variable was significant (p=0.001), meaning their answers differed significantly from those expected of a random distribution.

Table 2. Bottom-longliners' (n=49) knowledge regarding their socio-economic situation and earnings trends, Bejuco, Pacific coast of Costa Rica

Bejuco bottom-longline population socio-economic situation and earnings	Frequency of positive answers	% of population
My economic situation has not improved during my involvement with fishery	47	95.9
My future economic stability is in jeopardy	47	95.9

My exclusive earnings from fishing have been reduced in recent years	47	95.9
I cannot cover all of my household expenses with earnings from this fishery	41	83.7
The payment I receive per kg of snapper is unfair	46	93.9
If I used another gear type, I would earn more	18	36.7
Considering my earnings, I believe I will continue to fish this same way in the future	44	89.8
I have a good quality of life in this community	45	92.0

During the first focus group, held in Bejuco in September 2013, regarding how fishers have adapted their lives to compensate for the decline in fishery productivity, Bejuco's bottom-longline fishers and community members associated with fishing activities were adamant that despite their increasingly troublesome economic situations their communities are calm and beautiful places to live in. One fisher contextualized these feelings in the following way: "Here, we live differently than they do in San José; we get along with our fellow community members around us." When asked whether or not the presence of three independent associations and a large group of independent fishers strained relationships between bottom-longliners, one fisher commented thusly: "If a fishing boat is sinking, we all go out and help. That's why we're united even though we're in separate groups [associations]."

According to information collected by researchers through the survey, more than half (59.2%) of Bejuco fishers rent the boats they use and therefore share their earnings with the vessel's owner. Regarding alternative forms of employment, the majority of the respondents relies solely on bottom-longline activities for their income. Less than a third (28.6%) of the population works occasionally as day laborers at construction sites, in property maintenance, carpentry, agriculture, or fish sales. Because of their socio-economic reliance on fishing, they have had to economically adapt to the resource's availability. This adaptability allows them to create a way of life that traverses their economic hardships. A fisherman's wife summarized their lifestyle in the following way during the first focus group held in Bejuco in September 2013: "We settle for what the fishing brings us…it's all we have, there's no other way. We barter with other community members. We give them fish and get corn or squash or something else in return."

Because 36.7% of Bejuco's bottom-longline fishers feel they could improve their economic livelihoods by using another type of fishing gear, fishers were asked to explain their reasoning. Fishers stated during the first focus group held in Bejuco in September, 2013 that some of them are switching from bottom-longlines to gillnets because, "The fishing has been bad for the last two months" and that, "you can't catch anything with the line right now, but at least you can catch some snappers and other fish with the nets". According to interviews with the three local Bejuco fish buyers, the fishery, in the last decade, has experienced drops in production similar to the present one. Buyers noted that during these times fishers typically found work doing non-fishery related activities. During the 2013 downturn in production from May through the end of this study's field work in October, some fishers decided to change gear types, a decision that has allowed them to catch more snappers than other fishers who still used lines.

Regarding fisher opinions that the payments they receive per kilo of snapper are unfairly low, Bejuco's buyers mentioned that historically prices were lowest during the rainy season (May-November) due to a drop in national demand for the product caused by seasonal declines in tourism.

Bejuco bottom-longline users are convinced that their gear type is an effective way to catch snappers, and nearly all fishers believe that they will continue to use this technique as long as they continue locally fishing this species (Table 3). All respondents said it has had to use longer lines and more hooks then they did in the past to catch the same amount of snappers.

Table 3. Fisher knowledge regarding the population's (n=49) use of bottom-longlines, Bejuco Costa Rica

Bejuco fisher knowledge of bottom-longline use	Frequency of positive answers	% of population
Bottom longlines are an effective gear type for catching snappers	47	95.9
I now have to use longer lines than I did in the past	49	100%
I now have to use more hooks than I did in the past	49	100%
As long as I continue fishing, I will use this technique	43	87.8

The *p* value for grouped fisher responses to all items from this variable was not significant (p=0.547), meaning their answers did not differ significantly from those expected of a random distribution.

The interviews of the focus groups revealed that few options for alternative gear techniques and strategies are available for use in Bejuco. Because of this, fishers believed they will continue to use bottom-longlines in the future despite their declining economic situation. At the same time, however, fishers mentioned a growing tendency among their population to use gillnets instead of lines. They also mentioned that more fishers would use these nets if they were cheaper to obtain, but their high price (approximately US$ 800,) prohibits most fishers from purchasing them. Therefore, fishers mentioned that gillnets were for the most part implemented when a boat's owner was able to purchase and provide them to his working crew.

Notwithstanding, 30.6% of the respondents would like to switch gear types from lines to gillnets. The most commonly noted reasons for fishers wanting to change techniques were that nets catch more snappers than lines do, one can earn more using nets, and that nets only trap large snappers.

The respondents admitted to understanding the term "sustainable fishing" and believed its use of bottom-longlines is sustainable and does not negatively impact the environment or the snapper stock. In contrast to this, fishers mentioned that there are fewer snappers now than there were in the past, but that this decline was caused by a lack of government control over illegal fisheries operating in the area (Table 4).

Table 4. Fisher knowledge (n=49) regarding the sustainability of the bottom-longline activities, Bejuco, Pacific coast of Costa Rica

Bejuco fisher knowledge of bottom-longline sustainability	Frequency	% of population
The use of bottom-longlines is sustainable	48	98.0
I understand what sustainable fishing means	45	91.8
There were more snappers in the past than there are now	46	93.9
There is not enough governmental control over the state of the snapper stock	46	93.9

My fishing technique does not harm the environment	47	95.9

The *p* value for grouped fisher responses to all items from this variable was significant (p=0.017), meaning their answers differed significantly from those expected of a random distribution.

Fisher responses to open-ended survey question 40 on their definition of "sustainable fishing" included environmental and socioeconomic themes (Table 5). At the same time, 14.3% of respondents proclaimed that their fishery was sustainable, though they could not define the term.

Table 5. Answers to survey question 40 on bottom-longline fishers (n=49) definition of sustainable fishing, Bejuco, Pacific coast of Costa Rica

Fisher definition of sustainable fishing	# of responses	Percentage of fishers
One that does not destroy the resource	10	20.4
You can survive from the fishing	10	20.4
Causes the least amount of damage	10	20.4
You are not allowed to fish with illegal techniques	6	12.2
As long as there are fish, it is sustainable	3	6.1
You catch what you need and no more than that	3	6.1
I do not know	7	14.3
Total	**49**	**100%**

The fishery's three local buyers were asked about sustainable fishing as well. According to them, bottom-longlines capture large quantities of juvenile snappers, whose sizes are below the minimum size limit established by INCOPESCA (Costa Rica, 2013). Gillnet use on the other hand captures a larger percentage of adult (larger) size snappers and is therefore more sustainable, in terms of *Lutjanus guttatus* captures, than bottom-longlines are. Buyers also mentioned that when the fishing is good, fishers set their lines every night until catch rates drop off again.

According to 65.3% of the fishers, their activities are carried out without any formal snapper resource management strategies (question 42). Of the 17 (34.7%) fishers that did apply a fishing strategy, eight of them (47.1%) said that the use of bottom-longlines was their strategy. During the study's second *focus group in Bejuco in October 2013 one fisher justified the lack of a local management strategy in the following way: "We've always fished with lines and they don't destroy as much. The number of fishers and boats here has never changed. It is sustainable because it has always supported us."*

Despite the absence of management strategies that both regulate the fishing effort in Bejuco and define the appropriate gear type to be used, all five participants in the second focus group were united in their identification of a destructive fishery: the industrialized shrimp trawl fishery. During the study's second focus group, Bejuco fishers insisted that the presence of the trawl fishery in the area is the cause of dwindling snapper catch rates. This is because the trawl fleet's activities capture large quantities of snapper inside the area's two marine protected areas

(MPAs) where their presence is illegal, in addition to its legal activities in the unprotected area between these MPAs. Fishers went on to explain that the protected areas are multi-use MPAs that allow for the use of certain low-impact gear types including hand-lines and bottom longlines but prohibit more unselective techniques such as surface long-lines, gillnets and trawl nets. While permitted to fish inside the district's MPAs, Bejuco bottom-longliners primarily fish between the two protected areas because according to them there are more snappers in this unprotected zone. Bottom-longliners were quoted as saying, "If the government would keep them (shrimp trawls) out of these areas, there would be more snappers in the future". Fishers further commented that if INCOPESCA does not better enforce the MPAs in the near future, there would not be enough snappers to support the local small-scale industry. A local ASPEPUCO bottom-longliner contextualized the situation in the following way during the second focus group held in Bejuco in October 2013:

> *"In the past, the fishery always maintained itself, but this year it has dropped way off. Without the shrimp trawlers everything would recover and we would be able to fish the way we want to. But if things keep going the way they are, there won't even be a sea snake left."*

Not only do fishers believe that shrimp trawlers are destroying their livelihoods, but their presence inhibits Bejuco bottom-longliners from developing their own sustainability plans. This attitude was best described by one fisher in the following way during the second focus group held in Bejuco in October 2013:

> *"It is difficult. We are here doing everything the right way, and everyone else [shrimp trawlers] just come on in. We need to protect our fishing grounds and create another protected area because if the entire area is not protected the trawlers will come in. But we hardly have enough to eat – how are we supposed to create a management plan?"*

Bejuco bottom-longline fishers believed their snapper fishery has changed over time. Nearly all fishers (98%) felt they capture fewer snappers today than they did in the past, and respondents felt it has to fish longer today to catch the same amount of fish as it did in the past (Table 6). Because 59.2% of respondents believed that there has been an historical size change in snappers and 46.9% of them felt that the distance they have to travel to fish snappers has increased, these questions were posed to the fishery's three local buyers. According to information collected through interviews with the three buyers, fewer snappers were caught today compared with quantities from 10 years ago. These buyers also explained that average snapper sizes have not changed over the last 20 or more years. They also stated that Bejuco bottom-longline users fish snappers at the same established locations today as they did when the fishery began over 30 years ago. Buyers went on to explain that historically the snapper catch has demonstrated year round consistency with production peaks in the rainy season (July-October) and at the beginning of the dry season (December-January). Today, these production peaks have declined and there has been a leveling off of the snapper catch that is more or less the same all year round.

Table 6. Fisher historical knowledge (n=49) of the bottom-longline fishery, Bejuco, Costa Rica

Bejuco fisher historical knowledge of bottom-longline snapper fishery	Frequency	% of population

Snappers are smaller today than they were in the past	29	59.2
I now capture fewer snappers than I did in the past	48	98
The distance I travel to fish snappers has increased	23	47.0
I have to fish longer today to catch the same amount of fish as I did in the past	49	100

The *p* value for grouped fisher responses to all items from this variable was significant (p=0.001), meaning their answers differed significantly from those expected of a random distribution.

Additional survey questions designed to ask fishers about their historical knowledge of snapper and bycatch species tendencies revealed that 59.2% of fishers feel that historically they catch more snappers during the rainy season (question 43) than they do during the dry season. Furthermore, 71.4% of fishers identified the wet season as a time when more gravid females are caught (question 46). Fishers (53.1%) also mentioned to researchers that many types of bycatch species that were commonly caught in the past, are rarely seen today. Of these respondents, 50% said that sharks were the most notably depleted bycatch species. Other species that were once commonly caught but are not as prevalent today included barracuda, groupers, and congers.

Fisher comments regarding declining shark captures were also supported by local buyers who mentioned that in the past shark production peaked at the onset of the rainy season, but today this is no longer the case and there are no seasonal shark production peaks. During the conversations with the second focus group, the five participants blamed the destruction of other populations of fish (including sharks) on the unselective fishing techniques used by the national shrimp trawl fleet in the area.

DISCUSSION

Bejuco's bottom-longline fishers have created a society that reflects a common setting in SSF communities where culture, economy, and environment are effectively inseparable from one another (Newell & Ommer, 1999). In general, Bejuco's bottom-longline fishers demonstrated typical characteristics of the country's poor, rural populations. According to the Costa Rican National Survey and Statistics Institute's (INEC) 2013 National Homes Survey, Bejuco bottom-longliners' fishing activities constrain this sector to the non-extreme poverty category of the Institute's established levels of poverty for the region (INEC, 2013). While content with their quality of life in their communities, most Bejuco fishers have little access to alternative forms of employment and are therefore dependent on the income they derive from this fishery to cover their household expenses. Economic dependence of this nature by SSF fishers on the local resource is a common characteristic of this sector in developing countries and has been linked to resource degradation, poverty, and political and social marginalization (Allison & Ellis, 2001; Cinner, 2013). Further development of this fishery is also compromised by the lack of complete inclusion of the population into formal organizations, a prerequisite for the development of adaptive social-ecological management systems capable of confronting fisher poverty (Berkes, 2003).

The FAO currently urges fishers in these types of social situations to immediately begin searching for alternative employment options, keeping in mind that the coastal tourism industry could be an economically viable option and poverty alleviation strategy (FAO, 2014). Bottom-longliners' conviction that their economic wellbeing in the future will be worse than it presently is, is a sign of socio-economic vulnerability (Adger, Brooks, Bentham, Agnew & Eriksen, 2004). Because the collection of FEK reveals that fishers have a detailed understanding of their past and current economic states and how these correspond to the amounts of snappers they are able to catch, close attention on the part of fishery managers should be paid to these concerns because they clearly reveal the economic benefits that are derived from fishery resources. While an important component to this fishery's management, other aspects besides the snapper catch and fisher earnings derived from this catch play a role in determining the vulnerability of fishers to income poverty. Some of these include landownership, debt, access to health, education and financial capital, and marginalization from the political decision making process (Béné, 2009). The latter of these is certainly true for SSFs in Costa Rica where the sector is not politically represented to the extent that more industrialized fisheries are, something that will most likely worsen the socio-economic marginalization already being experienced within this sector (OLDEPESCA, 2014). Moreover, the fishery is not in the position to effectively lobby for more political representation, given its fragmented organizational structure where only slightly over half of its participants are members of organized associations.

While this development scenario paints a bleak outlook for Bejuco fishers, it does not necessarily mean that this population desires to leave its profession for an alternative occupation such as tourism. In fact, these snapper fishers agreed that they have a good quality of life in the district despite their economic hardships, and they have devised ways to mitigate their earnings shortcomings without leaving their profession. One of these ways is through their trade and barter system, an aspect of the fishery that was revealed during the first focus group. Such arrangements, where no remuneration is exchanged between parties, are a common trait of subsistence fisheries (Schumann & Macinko, 2007). Social systems such as this one demonstrate the presence of community-based solutions to development problems (St. Martin, 2006). In the case of Bejuco, this strategy offsets economic hardships and reflects a sense of adaptive capacity among fellow coastal residents. A natural progression of these social structures should ideally give rise to the development of community lead resource management strategies that address economic challenges brought about by fish fluctuations (Ramirez-Sanchez & Pinkerton, 2009).

This community unity is certainly something that supports fisher assertions that they will continue to fish snappers in the future. Similar social situations where fishers are satisfied with their jobs despite their economic situation have been reported by Pollnac, Pomeroy, & Harkes (2002) for communities of small-scale fishers in the Philippines, Indonesia, and Vietnam, and González (2011) for SSFs in Nicaragua. This type of job satisfaction often means that fisheries policy aimed at developing alternative employment options, like the FAO's recommendation that small-scale fishers seek more stable employment within the tourism industry, is destined to fail simply because fishers enjoy fishing for a living (Pollnac et al., 2002). Ultimately, the goal of any fishing community development strategy should be the improvement of the population's wellbeing as it relates to fisher valued freedoms, and good quality of life (McGregor, McKay, & Velazco, 2007; Coulthard, Johnson, & McGregor, 2011). Often times this concept of wellbeing is unrelated to one's economic state (González, 2011). For some fishing community members, as long as they have enough to eat, they do not consider themselves poor (González, 2011). This being the case, SSF development efforts cannot be solely focused on increasing fisher earnings because these have little to do with allowing fishers to act meaningfully to pursue their goals (McGregor et al., 2007).

In Bejuco, fisher knowledge of the use of bottom-longlines and their effectiveness to target snappers extends back to when the fishery began nearly 30 years ago and when its target species was less exploited. Despite their assertions that this gear type effectively catches snappers, fishers have had to increase their efforts (longer lines, more hooks, increased time spent fishing) in order to financially sustain themselves. Their assertions that they catch fewer snappers today than in the past are supported by INCOPESCA's historic snapper catch data that shows a 77.1% drop in snapper production in Guanacaste by the small-scale, medium and semi-industrialized fleets from 1990 (when the data set begins) to 2013 (INCOPESCA, 2015).

This type of fish stock decline occurs when fishing harvest rates exceed natural recruitment rates for the population (Smith, 1969), a process that has historically led to overfishing and overcapacity (Ward, Kirkley, Metzner, & Pascoe, 2004). FEK collected from this fishery reflects Gordon's (1954) classic analysis on simple economic theory where fishers experience high catch rates and high profits when they first begin to exploit an abundant resource. But, if fishing effort is left uncontrolled, it will increase and spread to other fisheries, creating a situation where harvest rates lead to stock decline. This decline in resource abundance then provokes competition between fishers and fisheries with individual fishers struggling to maintain their economic livelihoods.

This exact situation has happened in Bejuco where local fishers blame the presence of the shrimp trawl industry and its use of this gear type to catch snappers for the decline in their fishery's productivity. Furthermore, fishers are adamant that the removal of this fishery from the area would restore the snapper fishery to previous production levels. Globally, the overexploitation of fish stocks and the socio-economic impacts that have resulted from the decreased production of the world's fisheries has created conflicts between artisanal and industrial fisheries (Horta & Defoe, 2012). In Latin America this type of competition between small-scale and semi-industrial fleets is a common feature where antiquated top-down governance strategies favor large-scale extraction techniques and methods (Salas et al., 2007). Gillis & Frank (2001) showed how the local availability of Atlantic cod, in addition to changes in its abundance attributed to spawning and seasonal migrations, defined the dynamic allocation of fishing effort for this fishery. Therefore, it can be assumed that snapper life history traits dictate the spatio-temporal allocation of shrimp trawl effort, thus driving this resource conflict between the industrialized fleet and artisanal fishers.

The growing use of gillnets in Bejuco is perhaps a result of this conflict as well as a reflection of fishers' economic situation and growing desperation. Fisher motives that drive the use of alternative gear types to improve catch amounts are essentially economic (Crutchfield, 1961), though changes in fishing practices can also be focused on lowering fishery impact with the goal of creating long-term sustainable fisheries (Suuronen et al., 2012). In Bejuco, gillnet use more than likely has to do with improving fishing effort efficiency and profitability given declining bottom-longline catch totals. But at the same time, their use in the district is being supported by the local buyers because they believe the technique is more sustainable than bottom-longlines are because nets only catch large snappers. The fact that local buyers mentioned gillnet use as more sustainable compared to that of bottom-longlines shows how members of this industry are concerned with protecting the snapper population for its future local exploitation, even if the use of this technique is economically driven.

Because FEK collected for this study comprises multiple fisher perturbations concerning evolving fleet dynamics and resource abundance, a comparative analysis of the bottom-longline and gillnet catch should be undertaken in order for fishers to have a better understanding of how their decisions concerning gear type impact the future of the artisanal snapper fishery. Fishing gear and the way it is used influences the size frequencies of target species (Gobert, 1994). Artisanal gillnets have been shown to catch a wide variety of species, while at the same time being very size selective, capturing organisms of relatively narrow length ranges, depending on the mesh size (Acosta, 1994; Erzini, Gonçalves, Bentes, Lino, & Ribeiro, 1999) while longline catch is characterized by greater size frequency distributions of target species (Erzini et al., 1999). According to buyers, the mesh size used in Bejuco selects for larger snappers than bottom-longlines do, and gillnet use is therefore considered to be more sustainable. Fishers did not, however, mention how much bycatch is associated with gillnet use and if this amount is more or less than the amount caught with bottom-longlines. Furthermore, bycatch composition was not mentioned either. Studies have shown how species selectivity of these two gear types differs considerably (Erzini et al., 1999). Because of the tenuous economic state of this fishery, a clearer understanding of the selectivity differences associated with gillnets and bottom-longlines would allow fishery managers to better understand the overall ecosystem impacts of both gear types. For this reason, similar studies are recommended for the Bejuco artisanal fishery in order to better understand how the current mesh size, as well as other sizes, affects snapper size frequencies and bycatch quantities and composition, as well as how the total catch of these different gear modifications compares with the total bottom-longline catch (Wright & Richards, 1985). Lokkeborg, Humborstad, Jorgensen, & Soldal (2002) demonstrated how spatio-temporal variations in a North Sea gillnet fishery affect target species catch rates. Using these same methods, snapper catch rates from various points in and around locally used gillnet fishing areas could be analyzed. This type of research could identify fishing strategies that better allocate the gillnet effort and thus support sustainability strategies, as well as the efficiency and profitability of this fishery (Bastardie, Nielsen, Andersen, & Eigaard, 2010).

While there is a trend towards gillnet use in Bejuco that is associated with declining bottom-longline catch totals, it is important to bear in mind that although fishers are feeling pressure to switch gear types for economic reasons, they still believe that bottom-longlines are the most appropriate and sustainable way to fish snappers, despite buyer opinions. The sustainability label that has been placed on gillnets by these buyers may also be an excuse to promote their use during times of the year when fishers catch few snappers with bottom-longlines.

Fishers historically reconstructed a coastal ecosystem that contained not only more snappers, but one that included a greater abundance of most notably sharks, but other bycatch species as well. Overfishing has been shown to cause impacts on the structure and species composition of fish communities as well as changes to ecosystem structure through the loss of keystone species (Roberts, 1995, Greenstreet & Hall, 1996). Notable declines in coastal shark captures is not unique to Bejuco, having been documented in coastal areas around the globe (Baum *et al.*, 2003; Dudley & Simpfendorfer, 2006; Camhi, Valenti, Fordham, Fowler, & Gibson, 2009; Knip, Heupel, & Simpfendorfer, 2010). While pelagic sharks are also commonly targeted or caught as bycatch by high seas fisheries, many of these individuals survive to migrate to coastal waters to reproduce. Given this migratory nature, not only coastal fishing efforts impact shark populations, but deep-water trawl fisheries and even open-ocean pelagic fisheries also impact shark populations in coastal areas (Baum et al., 2003; Clarke, Espinoza, & Wehrtmann, 2014;). In these terms, the apex predator decline along the coasts demonstrates the impacts that multiple semi-industrial fisheries are having on Bejuco's fishing efforts. Trophic cascades caused by a decline in top predators – such as sharks – have been widely documented (Myers, Baum, Shepherd, Powers, & Peterson, 2007; Heithaus, Frid, Wirsing, & Worm, 2008; Worm et al., 2009). Comparative studies on lightly fished and heavily fished tropical reef ecosystems showed that the majority of fish biomass consisted of large apex preditors (including sharks) in areas of low exploitation whereas more impacted areas showed that herbivores and low-level small carnivores (including snapper) made up larger percentages of the total fish biomass (Friedlander & DeMartini, 2002). Understanding the roles that sharks play in influencing the mortality of their prey, in this case snappers, is therefore a critical piece of information required to understand effects that pelagic fisheries are having on coastal ecosystem complexity and health.

The bottom-longline, gillnet, shrimp trawl, and to some extent pelagic fishing fleets all interact to determine the fleet dynamics of individual fisheries whose efforts all target spotted rose snapper in Bejuco. The combination of these dynamics determine spatial-temporal characteristics including where fishers fish, how much they fish, as well as other aspects including how fishers use new fishing gear, and how they respond to changes in governance strategies (Branch et al., 2006). And while the dynamics of the shrimp trawl and other foreign fleets are beyond Bejuco fisher's control, what is within their power to influence is the task of self-organization into an effectively functioning association that has the capacity to govern bottom-longline and gillnet use in the district. Failure to do this will exacerbate the resource extraction pressures these fishers face. Already, because of a lack of organizational cohesion, they appear to be caught in a “tragedy of the commons” scenario (Hardin, 1968). In order to have any chance of escaping this situation, they must strengthen their own community-based institutions and develop locally representative participatory management strategies. This kind of alternative management structure should be adaptive and participatory in nature, so that it engages resource users’ knowledge (Berkes, 2003) in such a way that it uses local FEK to develop profitability and sustainability strategies. Any such governance system changes such as the one proposed here would need to be recognized and supported by INCOPESCA prior to its implementation. It would also benefit from constant stock and ecosystem monitoring initiatives by university researchers and NGOs.

Fishing communities that use their high level of local knowledge to define fishery related problems and possible solutions have been shown to successfully develop community-owned fisheries management plans and other locally based governance systems (King & Faasili, 1999). While this concept is not widely recognized by Costa Rican authorities, there has been some forward progress made on this front. INCOPESCA has recently created the Responsible Marine Fishing Areas (RMFA) management tool, a strategy designed to recognize coastal community organizations for their role in SSF governance (La Gaceta, 2009; Fargier, Hartmann, & Molina-Ureña, 2014). The RMFAs are intended to become a zoning instrument, regulating SSF activities within a designated area (La Gaceta, 2009). Local support for such a management strategy would, at the very least, compliment the development of fisher-led sustainability initiatives (FAO, 1995). Any management strategy for a fishery of this kind should also take into account its emerging multi-specific nature and fisher propensity to adapt efforts to its target species’ changing abundance trends (Naranjo-Madrigal & Salas-Márquez, 2014). Though fishing gear allocation in Bejuco appears to be shifting, bottom-longline spatio temporal-allocation of effort has not, as fishers continue to use the same traditional year-round sites to catch snappers. The FEK regarding historic catch trends and the identification of interdependencies with the trawl fleet should be considered if and when this process of redesigning the local management regime occurs. Shepperson, Murray, Cook, Whiteley, & Kaiser (2014) provided an example of how FEK and vessel monitoring system (VMS) data can be used to estimate fishing intensity among different fisheries. Such a system could possibly contribute to conflict resolution in artisanal and industrial fisheries through spatial planning initiatives in areas of multi-fishery competition in Bejuco.

The development of management schemes that identify the processes and causes of overfishing trends plays an important role in establishing and maintaining fishery production equilibrium as well (Allen & McGlade, 1986). In Bejuco the local knowledge of fishing effort combined with fishers’ historic understanding of stock trends and snapper length frequencies over the past few decades can be used to help determine future harvest strategies (Venables, Ellis, Punt, Dichmont, & Deng, 2009). An enforceable set of harvest control strategies, including the development of precautionary limit reference points that provide a framework within which a fishery management strategy could operate (Garcia, 1996; Caddy, 1998), should be developed in a joint process that involves both fishers, researchers, and INCOPESCA. Such an undertaking, if done correctly, could define a practical level of balance between snapper exploitation, the stock’s long-term production capacity, and the preservation of fisher livelihoods. In the case of Bejuco, fishing occurs year-round. Models depicting fishery closures during identified spawning seasons for coastal aggregate spawning species have shown this management tool to be an effective way for reducing fishing mortality rates (Fulton, Kault, Mapstone, & Sheaves, 2011). A fisher-supported closure in Bejuco could also be an integral part of the fishery’s harvest control plan and contribute to the recuperation of the snapper stock.

Management inefficiencies that lead to resource overexploitation are not confined to Costa Rica as similar SSF development issues plaque the artisanal fishing sector throughout the world’s developing nations (Allison & Ellis, 2001; Cinner, 2013). The use of FEK to develop more sustainable fishing strategies can therefore be applied to other SSFs in the region suffering from stock decline and governance deficiencies.

CONCLUSION

This study used quickly acquired, low-cost data in the form of Bejuco bottom-longline user knowledge to identify socio-ecological tendencies within this fishery. A surprising result of the study was the decision of local fishers to use gillnets to catch snappers and the assertion from buyers that their use is a sustainable way to catch this target species. From a spotted rose snapper life history perspective, their arguments appear valid, as gillnets catch large adult snappers that have been able to reproduce at least once in their lifetimes (A. Bystrom, pers. Obs.) where longlines capture snappers of more variable sizes, including juveniles (Bystrom, Wehrtmann, & Arauz, in prep). But the real ecological sustainability question remains in the comparison of bycatch and discard quantities that result from these two gear types. At the same time, RFMAs are being established for bottom-longline use but not for gillnet use, so there is an impediment to the development of these management areas in Bejuco if fishers are in the process of changing gear types. Or perhaps the impediment is in the RFMAs and the management category's non-recognition of gillnets as an acceptable gear type. While there is a lot more technical research to be done on this front, the FEK in this study has allowed for a clearer panorama of the Bejuco fishery's socio-ecological tendencies, and their place within the evolving spotted rose snapper fishery's dynamics up and down Costa Rica's Pacific coast.

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CAPÍTULO IV

Indicator-based management recommendations for an artisanal bottom-longline fishery in Costa Rica

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Abstract
Management recommendations that are based on easily interpreted conclusions regarding the state of a fishery can be an effective governance tool. In this study, the results of previously analyzed fisher ecological knowledge and seven years of catch data taken from an artisanal, bottom-longline fishery in Costa Rica were categorized into the fishery's sub-systems (natural, human, and management). These sub-systems were then divided into categories and a measurable set of indicators was developed for each of these categories. The traffic light method was then used to assign easily interpreted colors that denoted indicator performance. The colors (red, yellow, green) were based on reference points identified in management strategies in a variety of international fisheries through a review of the published literature. Management recommendations were then developed based on these results. While no restrictions on bottom-longline effort are recommended at this time, a stock assessment is suggested for the fishery's target species to better identify extraction reference points. While no changes in fishing gear and methods are recommended, research of the fishery's discards should be conducted. Because of fisher dependence on their industry, the development of alternative livelihood options is highly recommended, in addition to the development of alternative markets and sustainability certifications for snappers. Fishers are also encouraged to more effectively self-organize themselves into an association that has the capability of lobbying for increased enforcement of the fishing ground's protected areas from destructive fisheries. Fishers should develop a concise management plan and push for the development of participatory governance strategies between the artisanal sector and national regulating entities.

Key words
Small-scale fisheries, indicator-based management, wellbeing, Costa Rica, governance, traffic light method

INTRODUCTION

Small-scale fisheries (SSFs) play an important role in global food security and in the development of the global fishing effort (Swartz, Sala, Tracey, Watson, & Pauly 2010; Anticamara, Watson, Gelchu, & Pauly, 2011; Gagern & van den Bergh, 2013). Notwithstanding, increased production demands on this sector, exerted by growing coastal populations, have occurred (Mora, Myers, Coll, Libralato, & Pitcher, 2009; Worm et al., 2009; Andalecio, 2010;

Gagern & van den Bergh, 2013). With the possibility of climate change factors also contributing to the reduced productivity of tropical coastal ecosystems (Doney et al., 2012), the application of innovative development approaches to SSFs is becoming increasingly important. Some of these include the livelihoods approach (Allison & Ellis, 2001), co-management or community-based management systems (Castilla & Fernandez, 1998; Castilla & Defeo, 2001; Defeo & Castilla, 2005), and adaptive management strategies focused on maintaining the productive capacity and resilience of SSFs (Berkes, 2003). The process of designing and implementing such a management strategy must, however, support both social and ecological processes inherent in coastal fisheries (McClanahan, Castilla, White, & Defeo, 2008).

Artisanal fishers strive to improve their general wellbeing, one associated with food security, healthy environments, quality of social relations, and cultural values, by working in and making their livelihoods from exploiting coastal marine resources (Brook & McLachlan, 2008). This means that factors that allow fishers to meet their basic needs and valued freedoms, as well as ones that provide them with a good quality of life, are all intrinsic components of the social structure of SSFs (McGregor, McKay, & Velazco, 2007; Coulthard, Johnson, & McGregor, 2011). Because of this, fishers view their industry as more than just a job, but as a way of life (Pollnac & Poggie, 2008). It also means that fishers' wellbeing is often unrelated to their economic state (González, 2011). This being the case, there is an inherently high level of job satisfaction associated with members of this sector (Pollnac & Poggie, 2008), making wellbeing an intrinsic component to SSF governance.

Governance is the role of public and private interactions taken to solve, in this case, fisheries issues and problems (FAO, 2004; Kooiman, Bavinck, Jentoft, & Pullin, 2005). Whether formal or informal, by governments or other stakeholders, in the form of international agreements and commitments, or policies at national or local levels, governance is needed to guide actions and decisions that impact SSF management and development (FAO, 2004). Ineffective governance has plagued the fishing industry and been the catalyst for such sector dismantling activities as subsidy-fueled overcapacity and over-fishing, as well as illegal, unreported and unregulated (IUU) fishing (FAO, 2004). Overarching United Nations implementing agreements established to guide fish stock conservation strategies and the development of responsible fisheries have failed to curb over-fishing because of ineffective regional, national, and local management strategies, many of which stem from antiquated top down, command-and-control approaches (Berkes, Mahon, McConney, Pollnac, & Pomeroy, 2001). For this reason, evolving solutions are needed to strengthen governance systems, preferably, ones that focus on local perspectives and priorities (Bavinck et al., 2005; Fabinyi, Foale, & Macintyre, 2013). Therefore, today it is widely accepted that effective fishery governance should consider aspects of human behavior (Jacobsen, 2013) including fishers' ability to self-organize within the social and ecological domain of the fishery system (Mahon, McConney, & Roy, 2008).

Small-scale fishers who achieve a better understanding of these social-ecological interactions are one step closer to building desirable resilience in their industry (McConney, Medeiros, & Pena, 2013). But strengthening systems of social-ecological governance requires that fishers are given the opportunity to learn, adapt, and ultimately self-organize themselves (Mahon et al., 2008). This type of organization or interactive governance should be enhanced through appropriate policy inputs, including co-management strategies that foster the development of resilient social-ecological systems (Folke, Hahn, Olsson, & Norberg, 2005; Gibbs, 2009; Biggs et al., 2012). Therefore, participatory governance or co-management is a locally initiated aspect of governance that incorporates fisher-led actions aimed at improving the adaptive capacity of their fishery (Charles, 2011).

Indicator based-approaches to management are used to define the state of ecosystems and fisheries systems. Their aim is to monitor, assesses and understand the effects of human activities on natural systems, as well as the effectiveness of management measures and other decision-making processes (Charles, 2001; Rice & Rochet, 2005). In contrast to model-based approaches, indicator based approaches to management do not pretend to understand or measure causal relationships and all relevant fishery systems interactions and processes in detail. In indicator based-approaches, timely and useful information is used by decision makers to move the fishery towards sustainability (Rudd, 2003). Thus, the knowledge base for management includes indicators and qualitative predictions (Degnbol & Jarre, 2004; Degnbol, 2005). A management system such as this is based on "soft predictability", an approach that does not require a detailed understanding of the processes and the capabilities of quantitative predictions inherent to modern fishery management models basis (Degnbol & Jarre, 2004).

The traffic light method, as part of an indicator-based management approach to fisheries management, as first proposed by Caddy (1998), uses a universally recognized color coding design (green, yellow, red) to assess a range of fishery indicators (Halliday, Fanning, & Mohn, 2001; Caddy, 2002; Trenkel, Rochet, & Mesnil, 2007). These indicators have the advantage of being based on readily available data that can be calculated with minimal technical input and give results understood and accepted by non-technical personnel or stakeholders. They can include price and earnings fluctuations, species population dynamics such as mortality rates, catch rates, or levels of by-catch, as well as fishery performance information derived from fisher ecological knowledge and traditional experiences. Results of their color coding assessment trigger management responses based on the number of key indicators which have turned from green to either yellow or red and vice-versa (Caddy, 1998). Adopting such an approach to fishery management can potentially give fishers and stakeholders more control over their business and the way it is governed within the framework of the precautionary approach (FAO, 1996; Halliday et al., 2001). The traffic light method has been used as part of the management process for Northwest Atlantic shrimp and groundfish stocks (Halliday et al., 2001), the Torres Strait tropical rock lobster fishery between Australia and Papua New Guinea (Plagányi et al., 2013), and a battery of data-poor fisheries in southern Europe (Tzanatos et al., 2013), to name a few.

Because fishery managers in developing countries have limited access to sufficient time series of data for stock assessments (Costello et al., 2012; Carruthers et al., 2014), alternative approaches that determine potential changes in the fishery and ecosystem are often more appropriate than sophisticated mathematical analysis (Caddy, 2002). These approaches, however, must also take into account not just resource and data availability, but also that complex societal structures make the governance of the ecosystems - within which these resources exist - inherently difficult (Bodin & Crona, 2009). These socio-ecological intricacies are present along Costa Rica's Pacific coast where the country's small-scale fisheries (SSFs) operate. SSFs in Costa Rica are community-based and are considered to be an expression of local culture (Chang & del Río, 2004). The natural state of the coastal ecosystems in which these SSFs operate, however, is increasingly compromised by coastal development, pollution, destructive fishing gear types, illegal fishing, and the effects of climate change (Rojas, 1996a; Rojas, 1996b; Quesada-Alpízar, 2004; Alvarado, Cortés, Esquivel, & Salas, 2012). These factors have given rise to increasing amounts of SSF community members facing economic difficulties, food security issues, and threatened livelihoods attributed to decreasing catch amounts (Rojas, 1996a; Rojas, Maravilla, & Chicas, 2004; Araya et al., 2007; Allison & Ellis, 2001). In this context, the need to strengthen the SSF sector with emerging governance strategies is more and more recognized (Pauly, 1997; Allison & Ellis, 2001). For these reasons, the present study used the traffic light method to assess indicators from multiple studies (Bystrom, Wehrtmann, & Arauz (in prep.(a)); Bystrom & Wehrtmann (in prep.); Bystrom, Naranjo-Madrigal, & Wehrtmann (in prep.(b))) of catch composition data and social-ecological information from an artisanal fishing community located at the Pacific coast Costa Rica, Central America. The study aimed to incorporate these results into a series of management recommendations.

MATERIALS AND METHODS

Study area

The present study was conducted with the bottom-longline fisher population from the district of Bejuco located at the southwestern Pacific coast of Costa Rica's Nicoya Peninsula. Bottom-longline. Bejuco fishers target spotted rose snapper (*Lutjanus guttatus*) and other bycatch species with economic value during nightly fishing activities. Their fishing grounds are located both within and outside the Camaronal National Wildlife Refuge's multi-use marine protected area (MPA) and the Caletas-Arío National Wildlife Refuge's multi-use MPA (Fig. 1). These protected areas allow local community members to fish with bottom-longlines but do not permit the use of what are considered more destructive gear types including gillnets and trawl nets.

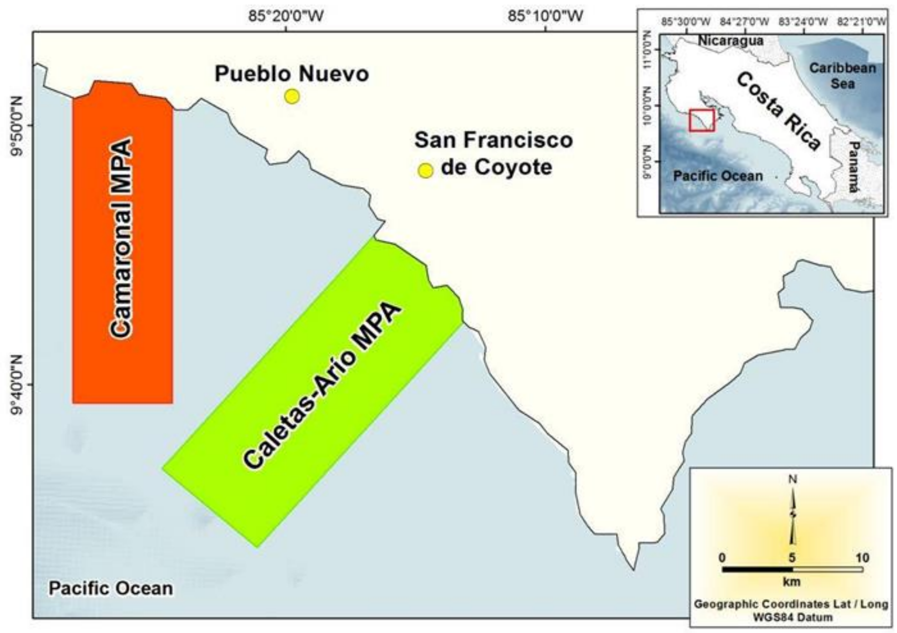


Fig. 1. Site map for data collection efforts that occurred with small-scale Bejuco bottom-longline fishers in the communities of Pueblo Nuevo and San Francisco de Coyote, Pacific coast, Costa Rica.

Traffic light technique

Lutjanus guttatus population dynamics, bottom-longline catch composition and selectivity, and FEK for the Bejuco bottom-longline fishery (Table 1) were taken from Bystrom et al. (in prep. (a)), Bystrom & Wehrtmann (in prep.), and Bystrom et al. (in prep. (b)). These results were first separated into the three major sub-systems that exist in fisheries as defined by Charles (2001): natural, human, and management. These sub-systems were then further divided into the following categories: (1) *Lutjanus guttatus* population dynamics, (2) bottom-longline catch composition and selectivity, (3) socio-ecological tendencies, and (4) governance, research and planning. A measurable set of indicators, whose status is a reliable way of determining the state of the resource and fisher socio-ecological systems (Sparre & Venema, 1997; Fischer, 2000; Gosse, Wroblewski, & Neis, 2001; Berkes & Folke, 2002; Murray, Neis, & Johnsen, 2006; Lutz & Neis, 2008; Nenadovic, Johnson, & Wilson, 2012), was then developed for each of these categories. Caddy's (1998) modified stoplight or traffic light approach was used to assign easily interpreted colors that denoted indicator performance in relation to findings identified in multiple independent publications. A green color or light indicated positive or increasing tendencies, a yellow light was assigned if no changes were noted or if there was not enough information available to confidently determine a trend, and a red light was assigned to indicators with negative or decreasing tendencies. Management recommendations were then made for each of the categories based on their indicators' colors.

Table 1. Results of *Lutjanus guttatus* population dynamics, bottom-longline catch composition and selectivity, and FEK studies with artisanal bottom-longline fishers in Bejuco, Pacific coast, Costa Rica (Bystrom et al. (in prep. (a)); Bystrom & Wehrtmann (in prep.); Bystrom et al. (in prep. (b))).

Study	Components	Results
Lutjanus guttatus population dynamics	Average snapper length (2007-2013)	Statistically significant increase
	Mortality rates and exploitation ratio	Natural mortality (M)=0.43 Fishing mortality (F)=0.34, Total mortality (Z)=0.77 Exploitation ratio (E)=0.44
Bottom-longline catch composition and selectivity	Snapper catch per unit of effort (CPUE) 2007-2013	No significant change
	Snapper size selectivity	84.6% are at or above the species' size at first maturity
	Target species selectivity	51.5% of all organisms captured
	Bycatch	48.5% of all organisms captured
	Discards	Estimated 10-20%
FEK	Economic dependence on fishery	71.4% of population have not developed alterative employment options
	Present and future economic situation	95.9% of population of fishers believe they have a declining economic situation and uncertain economic future.
	Wellbeing	92.0% of fishers believe they have a high quality of life
	Quantity of snappers in the past/future	93.9% of fishers believe there were more snappers in the past and there will be fewer in the future
	Fishing distances have changed	47.0% of fishers believe that the distances they travel to fish have changed
	Longline damage to sea bed	95.9% of population believe bottom-longlines do not harm the environment
	Disappearance of species	53.1% of the population believe that certain types of species commonly caught in the past are rarely seen today
	Level of fisher organization	Population dispersed between three associations that include 55.1% of

	fishers. Remaining fishers work independently
Presence of illegal fishing (national industrial fleet)	93.9% of fishers feel there is insufficient government control over illegal fishing
Management plan	No local management strategy exists
Catch monitoring and data collection	Entire population collaborates with researchers to collect catch data
Participatory governance	No recognized system exists in Costa Rica
MPA development	Two MPAs exists in the area. 100% of focus group participants agree that illegal fishing occurs in these areas

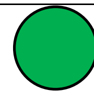
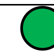
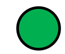
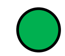
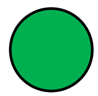
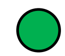
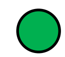
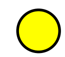
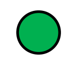
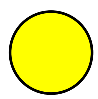
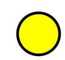
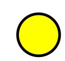
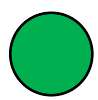
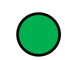
RESULTS

Green lights indicating favorable tendencies were assigned to both indicators for the *Lutjanus guttatus* population dynamics category because total spotted rose snapper lengths increased significantly from 2007-2013 and the population's exploitation level was at an acceptable level and lower than reported in other parts of Costa Rica. Two indicators analyzed in the bottom-longline catch composition and selectivity category (snapper size selectivity, target species selectivity) were also interpreted as favorable due to the percentage of mature adult snappers that were captured and the percentage of the total catch that was snapper (target species). The fisher wellbeing indicator in the socio-ecological tendencies (as defined by FEK) category also received a green light because of fishers' wellbeing in their communities and desires to continue fishing with the same gear type. The final indicator that received a green light (in the governance, research, planning category) was the high level of fisher participation in catch monitoring and data collection initiatives developed by various Costa Rican universities and environmental groups.

Red lights indicating declining or negative tendencies were assigned to indicators regarding fishers' economic dependence on their industry, their present and perceived future economic situation, and the quantity of snappers captured in the past as compared with fisher views of the future. All of these indicators were in the FEK category. A red light was also assigned to the discards indicator because they are above the global average for bottom-longline fisheries (Alverson, Freeberg, Pope, & Murawski, 1994). Regarding the Bejuco fishery's governance category, fisher associations demonstrated a low level of organization. Regarding the governance, research, and planning category, there was a high instance of illegal fishing from other fisheries in the area's two MPAs, and the fishery was without a management plan that clearly guided their actions. The status of these indicators is worsened by the lack of a nationally recognized participatory governance structure that promotes co-management governance initiatives. Because of these results, all of these indicators were assigned red lights.

All other indicators received yellow lights because they were found to have stayed the same or in some instances it was not possible to clearly identify their tendencies because of a lack of catch data and/or FEK. These indicators were: snapper CPUE and bottom-longline bycatch (both in the bottom-longline catch category), fishing distances have changed, longline damage to seabed, and the disappearance of species historically caught with bottom-longlines (both in the FEK category), and illegal fishing and MPA development (both in the governance, research, planning category). Table 2 contains the full list of all indicators, their assigned colors, as well as their comparison to other published studies and local observations made throughout this study.

Table 2. Results of the traffic light approach that assigned colors to indicators based on their trends in the Bejuco bottom-longline snapper fishery, Pacific coast, Costa Rica. Green lights were assigned to indicators demonstrating improving or increasing trends, red lights denote declining or deteriorating indicator trends, and yellow lights indicate no change or an absence of sufficient information.

SUB-SYSTEM	CATEGORY	INDICATOR	COLOR CODING FOR PRESENT STUDY	REFERENCE FOR COMPARED STUDY	FISHERY, TARGET SPECIES, LOCATION, OR RESEARCH TOPIC	COLOR CODING FOR COMPARED STUDY
Natural	***Lutjanus guttatus* population dynamics**	**Total lengths 2007-2013**		Stobart et al., 2009	Trammel net, *Palinurus elephas* , Mediterranean coast, Spain	
				Ault et al., 2005	Snapper-grouper complex Florida Keys	
				Shin et al., 2005	Size-based indicators to evaluate fishing impacts	
		Mortality		Cushing, 1968	Mortality and suitable exploitation ratios (E)	
				Gulland, 1971	Mortality and suitable exploitation ratios (E)	
				Amezcua et al., 2006	Shrimp trawl, *L. guttatus* Gulf of California, Mexico, age, growth, and mortality	
				Vargas, 1998-99	Gillnet and bottom-longline, *L. guttatus,* Gulf of Nicoya, Costa Rica	
	Bottom-longline catch composition and selectivity	**Snapper catch per unit of effort (CPUE) 2007-2013**		Walters, 2003	Analysis of spatial catch per effort data	
				Maunder et al., 2006	Interpreting CPUE for stock assessment	
		Snapper size selectivity		Mongeon et al., 2013	Bottom-longline, *L. guttatus* Bejuco, Costa Rica	

		Target species selectivity	🟢	Correa-Herrera & Jiménez-Segura, 2013	Artisanal hand-line, *L. guttatus*, Utría National Park, Colombia	🟢
				Erzini et al., 1999	Experimental longlines, *Merluccius merluccius, Conger conger, Polyprion americanus*, Algarve, Portugal	🟢
				Revolusi et al., 1999	Bottom-longline, *Lutjanus* spp., Indonesia	🟢
				Beltrano et al., 2004	Bottom-longline and gillnet, Scorpaenidae, Sepiidae, Octopodidae, Sparidae, Serranidae, Mullidae, Labridae, Egadi Islands, Italy	🟢
				Mamauag, et al., 2009	Artisanal longline, *Epinephelus coioides*, Philippines	🟢
		Bycatch	🟡	Lutchman, 2014	Use of bycatch % to develop a scoring system	🟡
		Discards	🔴	Alverson et al., 1994	Global bycatch and discard ratios (FAO)	🔴
				Kelleher, 2005	Central American artisanal fishery discard rates	🔴
Human	**Socio-ecological tendencies (as defined by FEK)**	**Economic dependence on fishery**	🔴	Daw et al., 2012	Western Indian Ocean, artisanal fisher adaptive responses and alternative livelihoods	🔴
				Emmerson, 1980	Philippines, Indonesia, Sri Lanka, horizontal fishery integration: opportunities for nonfishing employment	🔴

Present and future economic situation		FAO, 2014	Costa Rica, socio-economic pressures facing artisanal fisheries	
Wellbeing		Pollnac et al., 2002	Southeast Asia, fisher job satisfaction	
		González, 2011	Atlantic coast, Nicaragua, artisanal fishign community wellbeing	
		Blyth, 2013	Mozambique, Africa, social and ecological changes in coastal systems	
Quantity of snappers in the past/future		Ward et al., 2004	Overcapacity in artisanal fisheries FAO	
		Golden et al., 2014	Lutjanidae and others, Fiji, FEK to evaluate heavily targeted species in artisanal fisheries	
Fishing distances have changed		Van Holt, 2012	Dive fishery, Chile loco, *Concholepas concholepas*, Chile, Traditional ecological knowledge	
Longline damage to seabed		Sharp et al., 2009	Bottom-longline, *Dissostichus mawsoni*, New Zealand benthic impact assessment,	
Disappearance of species		FAO, 1984	A review of papers on the regulation of fishing effort	

		Level of fisher organization		Frangoudes et al., 2008	Improving fisher community organization and social dimensions strategies	
		Presence of illegal fishing (national industrial fleet)		Sumalia et al., 2006	Analysis of costs, benefits, and risks of IUU fishing, global context	
		Management plan		Jentoft, 1989	Co-management strategies for SSFs	
		Catch monitoring and data collection		Frangoudes et al., 2008	Shellfish, Galicia, Spain, avoiding overexploitation through data collection	
Management	**Governance, research, planning**	**Participatory governance**		Quesada-Alpízar, 2006	Costa Rica, encouragement for and limitations to participatory management in	
				Mahon et al., 2008	Enabling self-organization, learning and adaptation for the management of complex human-in-nature systems	
				Kearney et al., 2007	Canada, participatory governance for ecological sustainability and economic development	
		MPA development		Halpern, 2003	Density, biomass, size of organisms, and diversity inside marine reserves Global context	
				Alvarado et al., 2012	Costa Rica, coverage and threats to Costa Rican MPAs	

DISCUSSION

The traffic light technique proved useful for the evaluation of the state of the Bejuco bottom longline snapper fishery's natural, human, and management systems. Moreover, it also provided a platform upon which a set of recommendations could be formed and categorized. This type of indicator-based evaluation can be replicated to other artisanal fisheries in need of management improvements.

Lutjanus guttatus **population dynamics and bottom-longline catch composition and selectivity**

Snapper sizes increased from 2007-2013, which can be interpreted as an indicator that the fishery and gear type does not negatively impact the target species' stock (Ault, Smith, & Bohnsack 2005; Shin, Rochet, Jennings, Field, & Gislason, 2005; Stobart et al., 2009). To further emphasize this point, bottom-longline snapper CPUE from 2007-2013 showed no changes. Based on the results of these two indicators, the only management precaution recommended at this time regarding Bejuco bottom-longline effort is that it should not increase from its current levels. This recommendation should, however, be taken with a note of caution because fishers firmly agree that there are fewer snappers today than there were over a decade ago. Because the Costa Rican snapper fishery's fleet dynamics include the artisanal longline and gillnet sectors as well as the shrimp trawl fishery, it is possible that its technological interdependence is such that these different fisheries target and therefore impact different components of the snapper population's structure (Anderson & Seijo, 2010). For this reason basing management recommendations on size frequencies and CPUEs alone could be problematic (Walters, 2003; Maunder et al., 2006). With this in mind, a stock assessment is recommended for the fishery's target species, *L. guttatus,* in order to identify limit reference points. Emerging data-deficient methods used to analyze fish stocks have included catch data, similar to that collected by researchers in Bejuco, to determine sustainable yields for data-poor fishery resources (Cope & Punt, 2009; MacCall, 2009; Dick & MacCall, 2011). While these techniques should be used to further analyze the Bejuco bottom-longline fishery's data, they should be implemented in conjunction with strategies that continue monitoring snapper catch and environmental data for future analysis.

Snapper mortality is at an acceptable level according to Cushing (1968) and Gulland (1971). By comparison, it is lower than Vargas' (1998-99) study for the species in the nearby Nicoya Gulf and higher than the Gulf of California's stock (Amezcua, Soto-Avila, & Green-Ruiz, 2006). Because of the existence of other fisheries operating on the local snapper stock and their influence on snapper mortality, continued monitoring and enforcement measures to ensure that no illegal, unreported, and unregulated (IUU) fishing activities occur within the area's MPAs are advised. The fishery's multi-specific characteristics also attenuate this study's estimation of bottom-longline snapper mortality as an effective indicator of the stock's health because the cumulative impacts that other gear types (gill nets and trawl nets) exert on the stock were not considered. Giménez-Hurtado et al. (2005) estimated red grouper mortality in a multi-specific Mexican fishery and their methods would need to be applied to Bejuco's snapper fishery in order to obtain a more accurate estimation. A closer approximation of mortality, as well as a more accurate estimation of the snapper stock's unit and status (King, 2007), could also be obtained if the snapper fishery was homogenized to only allow one gear type. This would also make monitoring and management of this fishery more streamlined and effective.

Lutjanus guttatus represents 51.5% of the total number of organisms caught with bottom-longlines in Bejuco, far higher than target species caught with the same gear type in other reviewed tropical and subtropical coastal fisheries (Diplock & Dalzell, 1991; Erzini, Gonçalves, Bentes, Lino, & Ribeiro, 1999; Revolusi, Wibowo, & Sahari, 1999; Beltrano et al., 2004; Mamauag, Aliño, Gonzales, & Deocadez, 2009; Olavoa, Costa, Martins & Ferreira, 2011). The results of Mongeon, Granek & Arauz (2013) confirmed that the hook sizes currently in use in Bejuco adequately select for mature snappers. In this regard, no changes in fishing gear and methods are recommended as long as fishers carry out their activities in conformity with national fishing laws. Attention, however, should be paid to the fishery's bycatch amounts, which can be considered moderate according to Lutchman (2014). Because it is unclear the proportion of this bycatch that is commercialized or consumed locally and how much is discarded, additional data are required to better determine this fishery's ratio of discards because they are estimated to exceed global averages.

Socio-ecological tendencies

The Bejuco bottom-longline fishery is the only source of income for 71.4% of its fishers and any negative changes to the snapper stock would disrupt their abilities to maintain their economic livelihoods (Bystrom et al., in prep.(a)). Daw et al. (2007) showed how lower-income artisanal fishers tend to be more willing to leave the fishing activity than those who earn higher wages. This does not seem to be the case in Bejuco where impoverished fishing community members insist they will continue to fish in the future despite their bleak economic outlook, a decision that is related to their perceived wellbeing in their communities (Bystrom et al., in prep.(a)). While fishers in general are apprehensive about a career change because of their limited skills and educations (Sumaila, Teh, Cheung, Cornish, & Chu, 2008), alternative employment in the marine recreation industry is a growing option for some fishers (FAO, 2014). Because of this, development of alternative livelihood options is highly recommended to improve fisher resilience to socio-ecological change, though it is questionable whether or not fishers will agree to undertake these activities (Pollnac, Pomeroy, & Harkes, 2002). Along with pursuing alternative economic options, fishers are encouraged to develop alternative markets for spotted snappers. International sustainability certifications have been shown to add value to seafood products caught with sustainable methods (MSC, 2014), and their development in Bejuco could allow fishers at least to economically maintain their households while preserving their livelihoods.

Fishers feel there were more snappers in the past than there are now and that there will be even fewer snappers in the future. The FEK used to understand historic snapper and bycatch species population trends can and should also be considered in Bejuco for all management decisions (Pauly, 1995; Fischer, 2000; Gosse et al., 2001; Berkes & Folke, 2002; Murray at al., 2006; Lutz & Neis, 2008; Nenadovic et al., 2012). Because fishers have witnessed the declining population of their target species as well as catch declines of certain bycatch organisms (such as sharks, barracudas, groupers, and congers), proactive management decisions that work to reverse this tendency must be immediately considered. These need to include increased enforcement of the fishing ground's protected areas in order to curb IUU fishing, continued monitoring of catch rates and sizes, and a reduction in fisher economic dependence on this activity. Because MPAs have great potential to restore marine biodiversity at the species and community level (Bohnsack, 1990), fishers are encouraged to lobby for cross-sectorial governance strategies that would give them more control over local resource exploitation, including the creation of a locally managed, comprehensive MPA located in the fishing ground's unprotected areas that would better protect the snapper stock from destructive fisheries operating in the area.

Governance

Costa Rica has developed MPAs primarily designed to protect endangered marine species. The country is also implementing small-scale fisheries strategies based on a system of responsible fishing areas. This marine management strategy is considered by the country's Commission for the Seas (CONAMAR) – a governmental body formed in 2013 to create a national political marine development and conservation agenda – to be uncoordinated and lacking civil society participation (CONAMAR 2013). There is also an omnipresent lack of financial and human resources in Costa Rica that does not allow any marine managed areas to operate with enough personnel to implement a full management plan (Alvarado et al., 2012). Moreover, the country does not have a marine vessel to collect fisheries data. Local fisher participatory governance and data collection strategies could relieve some of this pressure. While no systems of community-based governance exist in Costa Rica, many small-scale fishing communities, as well as national governmental organizations, are interested in promoting the creation of such systems (CONAMAR, 2013). These initiatives should continue with increasing force as the development of local management systems has been demonstrated to be an effective institutional arrangement for small-scale Latin America fisheries in which fishers, scientists and managers interact to improve the quality of the regulatory process (Castilla & Defeo, 2001).

In light of these governance challenges and opportunities, the Costa Rican Fisheries and Aquaculture Institute (INCOPESCA), Costa Rica's national fisheries governing entity, created a management tool called Responsible Marine Fishing Areas (RMFA) (La Gaceta, 2009). The RMFAs are based on the FAO's Code of Conduct for Responsible Fisheries (1997) and are intended to become a zoning instrument regulating SSF activities within a designated area (La Gaceta, 2009). The establishment of an RFMA in the unprotected area between the two existing MPAs inside the Bejuco fishing grounds could provide the framework for more effective fishery governance. The development of such an area, though, would need to be accompanied by a process of fisher capacity building in order to give these local community members the tools and opportunities to manage their actions within the legal structure of an RFMA. Because fishers are currently dispersed among three associations (Bystrom et al. (in prep. (a))), they are encouraged to form one association whose unified voice can more effectively advocate for capacity development assistance, national regulations, and management suggestions such as those established for RFMAs. Data collection and stock monitoring would also be facilitated if this population of fishers would be more cohesively assembled. It is, however, not sufficient to dispose of the existing associations if a new all-inclusive entity is without the necessary capacity and authority to implement these management suggestions.

The current ineffectiveness of the three associations is compounded by the fact that the fishery has no management plan for the spotted rose snapper or commonly caught bycatch species. Because *L. guttatus* is a species with a low growth rate, its population requires prudent management (Amezcua et al., 2006). Therefore, the recommendations of the present study should be used to develop a concise local bottom-longline management strategy that includes snapper maximum sustainable yield, ecosystem impact mitigation, and fishery socio-economic development as its principal objectives. Bejuco fishers already have an advantage in this regard because they have participated for the past seven years in catch data collection activities with researchers, putting at their disposal valuable information regarding this stock's status.

The persistence of illegal shrimp trawl activity within the Bejuco fishing grounds' MPAs (Bystrom et al., in prep.(a)) and the high rate of capture of juvenile snappers in trawl nets in Central America (Andrade-Rodriguez, 2003) make sustainable management of the local *L. guttatus* stock a challenge no matter how much catch data is collected from bottom-longliners. For this reason, INCOPESCA must also improve its capacity to develop, implement, and monitor resource management measures including gear restrictions within these multi-use MPAs where bottom-longline and hand-line use is permitted but gillnets, trawl nets, and surface longlines are not. On paper, coastal MPA coverage in Costa Rica is considered to provide adequate conditions for the dispersion and exchange among populations of marine organisms (Halpern, 2003); however, few criteria or technical studies have contributed to their establishment (Alvarado et al. 2012). Insufficient financial, human, and material resources have been allocated to these protected areas by the national government to appropriately confront overfishing and illegal fishing concerns (to name a few) (Alvarado et al. 2012). Because the Bejuco MPAs are marine extensions of terrestrial wildlife refuges, they do not have their own management plans (Alvarado et al. 2012), and the development of fishery management plans that take into consideration any locally adopted bottom-longline management strategies (such as the one already suggested) for both of the area's MPAs is recommended as a building block towards community lead MPA management regimes.

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CONCLUSIONES Y RECOMENDACIONES

Se realizó el presente estudio debido a la importancia económica del pargo manchado, *Lutjanus guttatus*, los riesgos socio-ecológicos que las comunidades de pescadores artesanales enfrentan en términos de la producción de sus pesquerías y el bienestar económico de ellos y sus familias, la falta de suficiente información técnica acerca de la especie y la ausencia de estudios sociales sobre las percepciones de los mismos pescadores acerca del estado de los recursos pesqueros aprovechados por ellos.

El análisis de las características biológico-pesqueras reveló que los pargos capturados por los pescadores artesanales de Bejuco presentan tallas más grandes ahora que en el 2007. El arte de pesca que utilizan los pescadores de Bejuco, aunque resulta en la captura de juveniles, no captura tantos individuos inmaduros como otros estudios revelaron en diferentes partes de México (Arellano-Martínez, Rojas-Herrera, García-Domínguez, Ceballos-Vázquez, & Villalejo-Fuerte, 2001; Sarabia-Méndez, Gallardo-Cabello, Espino-Barr, & Anislado-Tolentino 2010), América Central (Andrade-Rodríguez, 2003) y América del Sur (Correa-Herrera & Jiménez-Segura, 2013). La mortalidad de la especie es más baja que en otras poblaciones de Costa Rica (Vargas, 1998-99), también mostrando que la población de pargos de Bejuco es menos explotada que otras del país, posiblemente causado por la presencia de las dos AMPs del distrito.

El análisis de las percepciones de los pescadores artesanales del distrito de Bejuco sobre la sostenibilidad de su actividad dejó ver la complejidad de los sistemas sociales y ecológicos dentro de los cuales los pescadores desarrollan sus trabajos y sus vidas. Además, la combinación del análisis cualitativo con lo cuantitativo permitió analizar ambos conjuntos de resultados para poder identificar las opiniones de ellos. Si no se hubiera realizado este estudio con métodos mixtos, se habría dejado por fuera la recolección de información acerca de componentes claves como las tendencias socio-ecológicas de este sector para el entendimiento del comportamiento de la pesquería. Los resultados, incluyendo la situación económica actual de los pescadores, la problemática de la pesquería, sus características socio-demográficas y el nivel de pobreza, sistemas locales y nacionales de gobernanza y su organización interna contribuyeron, más que cualquier otro componente analizado de este estudio, al conjunto de recomendaciones que se hicieron para la pesquería.

Para hacer estas recomendaciones, se aplicó una aproximación basada en indicadores llamada técnica de semáforo. La técnica sirvió como una plataforma para el desarrollo de las recomendaciones de manejo para la pesquería con líneas de fondo para el pargo manchado en el distrito de Bejuco.

Características biológico-pesqueras del *Lutjanus guttatus*, composición de las capturas con líneas de fondo y selectividad

Considerando los resultados del presente estudio, se recomienda que el esfuerzo pesquero no supere los niveles actuales. Por ser una pesquería mixta, es probable que el esfuerzo espacio-temporal de la flota trasmallera y camaronera este impactando el stock de pargo sobre diferentes etapas de su ciclo de vida. La colecta de datos de captura tomados por solo la flota liniera y su análisis no es suficiente para determinar el estado real de recurso en el área de pesca. Por eso se recomienda colectar información técnica pesquera acerca de estas pesquerías acerca de sus capturas de *L. guttatus.* Luego de la recolecta de esta información se podría realizar una evaluación del stock de pargo manchado a lo largo de la costa pacífica de Costa Rica para identificar el rendimiento máximo sostenible de pargo y que los pescadores sigan con su sistema de colecta de datos (en conjunto con investigadores) tomados por todas las diferentes pesquería que operan en la zona. Debido a las altas tasas de captura incidentales y la incertidumbre sobre la cantidad actual de descartes, se hace necesario llevar a cabo un estudio para identificar la proporción de capturas que no tengan valor económico y que a la vez no sean consumidas por los mismos pescadores y sus familias. Esto es importante para determinar si los descartes superan a los promedios internacionales o no.

Los pescadores también deberían seguir monitoreando las capturas para poder notar posibles cambios a lo largo de los años. Ellos mencionaron que existen algunas especies que hace una década eran prevalentes y que ahora no se capturan mucho. De igual forma se han demostrado como los fenómenos climáticos de El Niño y La Niña, caracterizados por los cambios en las temperaturas de las aguas superficiales, como pasó en el Pacífico tropical Oriental en el 2010 (NOAA, 2014), podrían causar fluctuaciones en las abundancias de organismos marinos-costeros (NASA, 2008; Riascos, Heilmayer, & Laudien, 2008; Gaymer, Palma, Vega, Monaco, & Henríquez, 2010). Por eso es importante trabajar con investigadores en la toma de datos de estas especies para tener un mejor entendimiento de sus épocas reproductivas, sus tallas de primera madurez para luego elaborar en forma conjunta estrategias para la conservación del recurso.

Tendencias socio-ecológicas

Debido a la dependencia económica que presentan los pescadores a su actividad, se recomienda que los pescadores empiecen a desarrollar opciones alternativas de trabajo (como el turismo que es una industria cada año más notable en el distrito de Bejuco) en el caso de que su industria sufra un colapso en el futuro por parte de los cambios climáticos, la sobre pesca o por otra razón. También se recomienda que los pescadores busquen la posibilidad de abrir mercados alternativos para el pargo manchado. Conseguir una certificación internacional de la sostenibilidad de la pesca del pargo manchado con líneas de fondo podría ser una manera efectiva para impulsar el desarrollo socio-económico de esta pesquería y se recomienda que los pescadores averigüen como empezar a desarrollar este tipo de iniciativa. Se recomienda que los pescadores de Bejuco formen una sola asociación, la cual tenga la capacidad de monitorear y controlar a la actividad pesquera de sus miembros y a la vez facilite la continuidad de la recolección de datos pesqueros. Además, se recomienda que esta nueva entidad legal tenga mejor control sobre las ventas del pargo manchado para poder establecer precios de pargo y de otros organismos con valor económico más justos y representativos de sus esfuerzos.

Gobernanza

Se recomienda que se establezca una nueva área de manejo (podría ser un Área Marina de Pesca Responsable (AMPR) o un Área Marina de Manejo) entre las dos AMPs ya existentes para que toda la zona pesquera de Bejuco esté bajo protección. Luego se tendrá que formar un sistema para su manejo comunitario que sea dirigida por los mismos pescadores de Bejuco en conjunto con las autoridades nacionales de INCOPESCA y MINAE. Un ejemplo de esta forma de co-manejo podría ser la creación de un AMPR, la cual sea establecida bajo el auspicio de INCOPESCA y manejada por los pescadores locales, dándoles la autoridad y la responsabilidad de monitorear la pesca del pargo manchado, solo permitiéndoles el ingreso a pescadores quienes estén de acuerdo con el uso de las técnicas de pesca aprobadas para esta área. A la vez, se recomienda que los pescadores de Bejuco diseñen un plan de manejo pesquero local, el cual tenga incluido estas sugerencias y que sirva como una manera para incentivar al INCOPESCA en el reconocimiento de los sistemas de co-manejo y que trabaje con los pescadores del distrito para establecer una forma de gobernanza local respaldado por el gobierno nacional. Un manejo de este estilo aliviará una parte de la responsabilidad del gobierno nacional y dará más autoridad a la asociación local.

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ANEXOS

ANEXO A
Cuestionario

Universidad Estatal a Distancia (UNED)
Sistema de Estudios de Postgrado (SEP)
Maestría en Manejo de los Recursos Naturales

Guía de cuestionario individual acerca de las percepciones socio-ecológicas por los miembros de las asociaciones de pescadores del distrito de Bejuco

N° de entrevista: ________________________ Fecha de la entrevista: ________________ Entrevistador: _______________________________________ Lugar de la entrevista: ________________________________ Objetivo: Describir la sostenibilidad pesquera del pargo manchado percibida por los miembros de ASPECOY

Buenos días/tardes. Mi nombre es Andy Bystrom, vengo de la Universidad Estatal a Distancia (UNED). Soy estudiante de la Maestría de Manejo de los Recursos Naturales, dentro de la cual estoy realizando mi proyecto de investigación de tesis con la finalidad de ver el estado real de la pesca del pargo manchado local por ustedes, los pescadores de las asociaciones de pescadores del distrito de Bejuco, y conocer cómo ven el presente y futuro de su industria. Quisiera saber si me puede colaborar con una entrevista para conocer su opinión, su conocimiento y algunos aspectos generales acerca de este tema. Le agradecería si me dedicara algunos minutos de su tiempo para conversar al respecto. Le agradezco por el tiempo y la ayuda brindada. **CABE RESALTAR QUE NO HAY RESPUESTAS BUENAS NI MALAS Y LA INFORMACIÓN SUMINISTRADA ES ESTRICTAMENTE CONFIDENCIAL PARA USO DE LA INVESTIGACIÓN.**

Muchas Gracias,

Andy Bystrom

I PARTE

Instrucciones: A continuación se le presenta una serie de preguntas, las cuales deben marcarse y/o contestarse en el espacio designado.

Características generales de la persona entrevistada

1. Edad_______

2. Nombre de la asociación a la cual usted pertenece
1 ASPECOY
2 ASPEPUCO
3 ASOBEJUCO

3. ¿Cuál es su estado civil?
1 casado
2 soltero
3 viudo
4 divorciado/separado
5 Unión libre

4. ¿Cuál es su nivel educativo?
1 Primaria incompleta
2 Primaria completa
3 Secundario incompleta
4 Secundaria completa
5 Universidad incompleta
6 Universidad completa
7 Otro_____________________

5. ¿Cuántas personas viven en su vivienda?
N° personas ________

6. Su vivienda es:
1 propia
2 alquilada
3 prestada
4 está en precario o tugurio

7. ¿Cuál es el material de sus paredes?
1 Block o ladrillo
2 Madera
3 Zinc
4 Otro

8. ¿La vivienda tiene cielo raso?
1 Sí
2 No

9. ¿Cuántos cuartos para dormir tiene su vivienda?
N° cuartos ________

10. Su vivienda cuenta con cuál de las siguientes características:

Característica	1 **Sí**	2 **No**
1 Agua del acueducto		
2 Pozo		
3 Servicio sanitario		
4 Luz eléctrica		
5 Cocina con gas o eléctrica		
6 Cocina con carbón		

11. Su vivienda tiene:

Objeto	1 **Sí**	2 **No**
1Teléfono		
2 Celular		
3 Refrigeradora		
4 Lavadora		
5 Televisor a color		
6 Televisor por cable		
7 Computadora		

12. ¿Es usted dueño de la panga que utiliza para sus faenas de pesca?
1 Sí
2 No

13. ¿Cuántas viajes de pesca a la semana realiza usted?
N° viajes ________

14. ¿Es la pesca la fuente de ingresos principal para el hogar?
1 Sí
2 No

15. ¿Cuántos años lleva usted pescando el pargo manchado en Bejuco?
N° años ________*
*15.a Si su respuesta es superior a los 10 años, indique el tamaño, la cantidad y el peso de pargo manchado que pescaba hace más de 10 años:

1 **Tamaño**	1 Más grande	2 Igual	3 Más pequeño
2 **Cantidad**	1 Más	2 Igual	3 Menos

16. ¿Realiza usted otro trabajo?
1 Sí*
2 No
*16.a Si la respuesta es Sí, ¿Qué tipo de trabajo y cuántas horas a la semana le dedica a este trabajo?

1 Tipo de trabajo__________
2 Cuántas horas a la semana__________

17. ¿Le trae beneficios pertenecer a la asociación?

1 Sí*
2 No

*17.a Si la respuesta es Sí, ¿Cuáles beneficios le trae a usted la asociación?

II PARTE

Instrucciones: A continuación se le presentan una serie de ítems en los cuales debe marcar con un (✓) en la casilla según corresponda. Ser precisos en sus comentarios

Guía de ítems concretas en torno al objetivo

Tendencias socioeconómica	**Muy en des-acuerdo 0**	**Des Acuerdo 1**	**De Acuerdo 2**	**Muy de acuerdo 3**
18. Mi situación económica ha mejorado durante el tiempo que he dedicado a la pesca del pargo manchado	0	1	2	3
19. Creo que la estabilidad económica de mi hogar en el futuro está asegurado con la pesca	0	1	2	3
20. Mis ingresos (con **SOLO** lo que gano de la pesca) se han visto reducidos en los últimos años	0	1	2	3
21. Debido a las ganancias, quiero seguir pescando pargo manchado en el futuro	0	1	2	3
22. Yo pudiera ganar más si usaría otra técnica	0	1	2	3
23. Tengo una buena calidad de vida en esta comunidad	0	1	2	3
24. Considero que con las ganancias exclusivamente de la pesca puedo cumplir con todos los gastos (familiares)	0	1	2	3
25. El pago/kg del pargo manchado que recibo es justo	0	1	2	3
26. La técnica (línea de fondo) que uso es una manera efectiva para pescar los pargos	0	1	2	3
27. He tenido que usar una línea madre más largo para poder capturar más pargos	0	1	2	3
28. He tenido que usar más anzuelos para poder capturar más pargos	0	1	2	3
29. Mientras sigo pescando, pienso usar la línea de fondo	0	1	2	3

Tendencias ecológicas	Muy en des-acuerdo 0	Des Acuerdo 1	De Acuerdo 2	Muy de acuerdo 3
30. En mi opinión, la pesca de pargo manchado con líneas de fondo es una forma sostenible de pescar	0	1	2	3
31. Yo entiendo qué significa la pesca sostenible	0	1	2	3
32. En mi opinión, habrá más pargos manchados en el futuro	0	1	2	3
33. Pienso que existe suficiente control y protección del estado sobre la sobre pesca del pargo manchado	0	1	2	3
34. La técnica de pescar que utilizo hace daño al ambiente	0	1	2	3
35. Los pargos que capturo ahora son más pequeños que los que capturaba antes con líneas de fondo	0	1	2	3
36. Capturo más pargos por viaje ahora que cuando empecé a pescar con una línea de fondo	0	1	2	3
37. La distancia que viajo en panga para encontrar y pescar pargos manchados ha aumentado durante el tiempo que he pescado en esta asociación	0	1	2	3
38. Hoy día tengo que pescar por más horas para logar capturar las cantidades de pargos que antes capturaba en menos tiempo	0	1	2	3

39. Le gustaría usar otra técnica de pesca
1 Sí*
2 No

*39.a Si la respuesta es Sí, ¿Qué técnica y por qué?

1 Técnica___________
2. Por qué____

40. ¿Qué significa pesca sostenible para usted?

____

41. ¿Antes se pescaban otros tipos de peces que ahora no se encuentran?
1 Sí*
2 No

*41.a Si la respuesta es Sí, ¿Cuáles especies de peces (no incluyendo el pargo manchado) ha cambiado durante el tiempo que usted ha dedicado a pescar?

____

42. ¿Aplica usted una estrategia para proteger la población de pargos manchados?
1 Sí*
2 No

*42.a Si la respuesta es Sí, explique su estrategia

____

43. ¿En qué época se pescan más pargos manchados?

1 Entrada de verano | 2 Verano | 3 Entrada de invierno | 4 Invierno

44. ¿En qué época se pescan menos pargos manchados?

1 Entrada de verano | 2 Verano | 3 Entrada de invierno | 4 Invierno

45. ¿En qué época se pescan pargos que miden menos de 34cm?

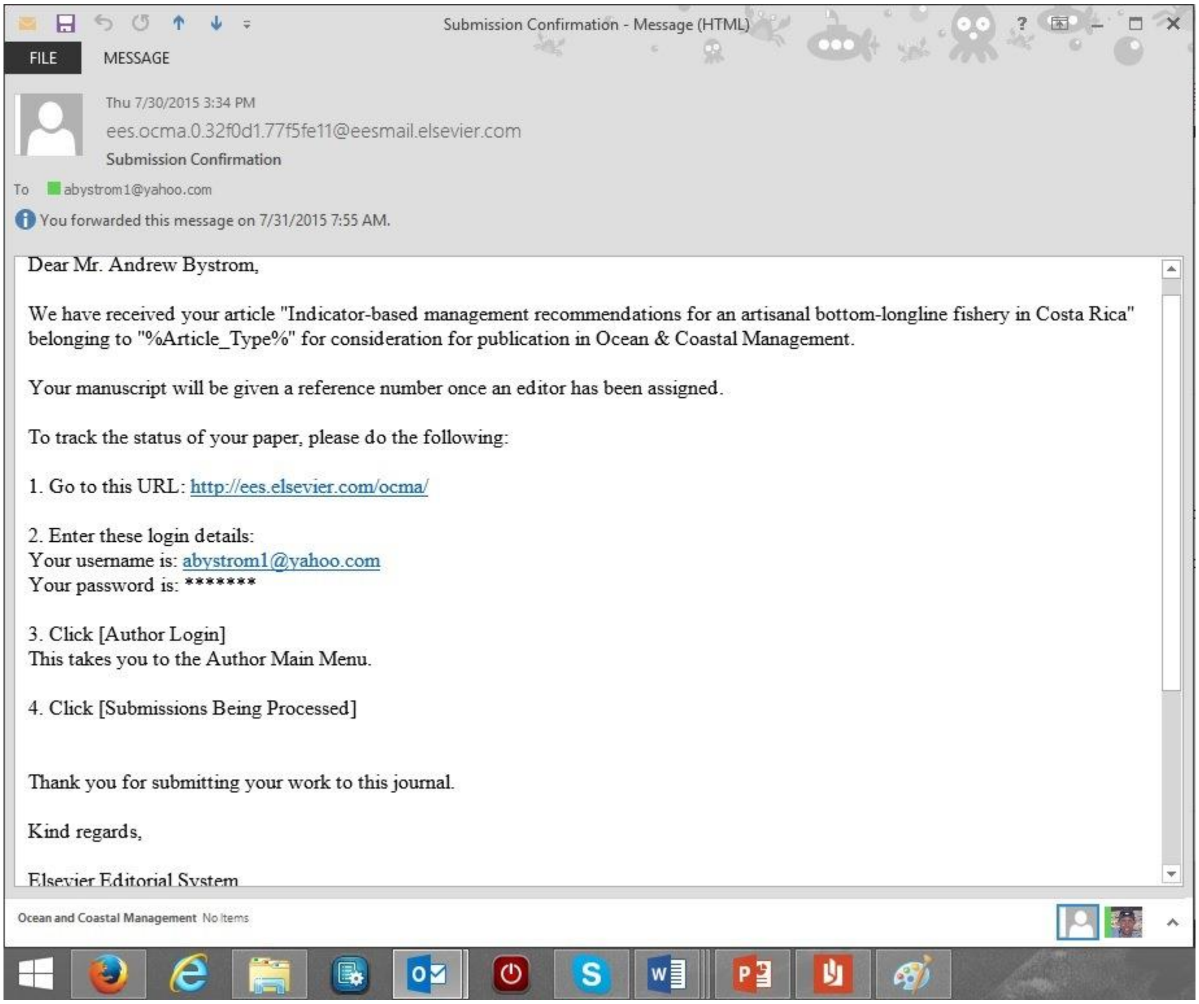
1 Entrada de verano | 2 Verano | 3 Entrada de invierno | 4 Invierno

46. ¿En qué época se pescan más hembras con huevos?

1 Entrada de verano | 2 Verano | 3 Entrada de invierno | 4 Invierno

ANEXO B

Carta de recepción del artículo (capítulo 4)



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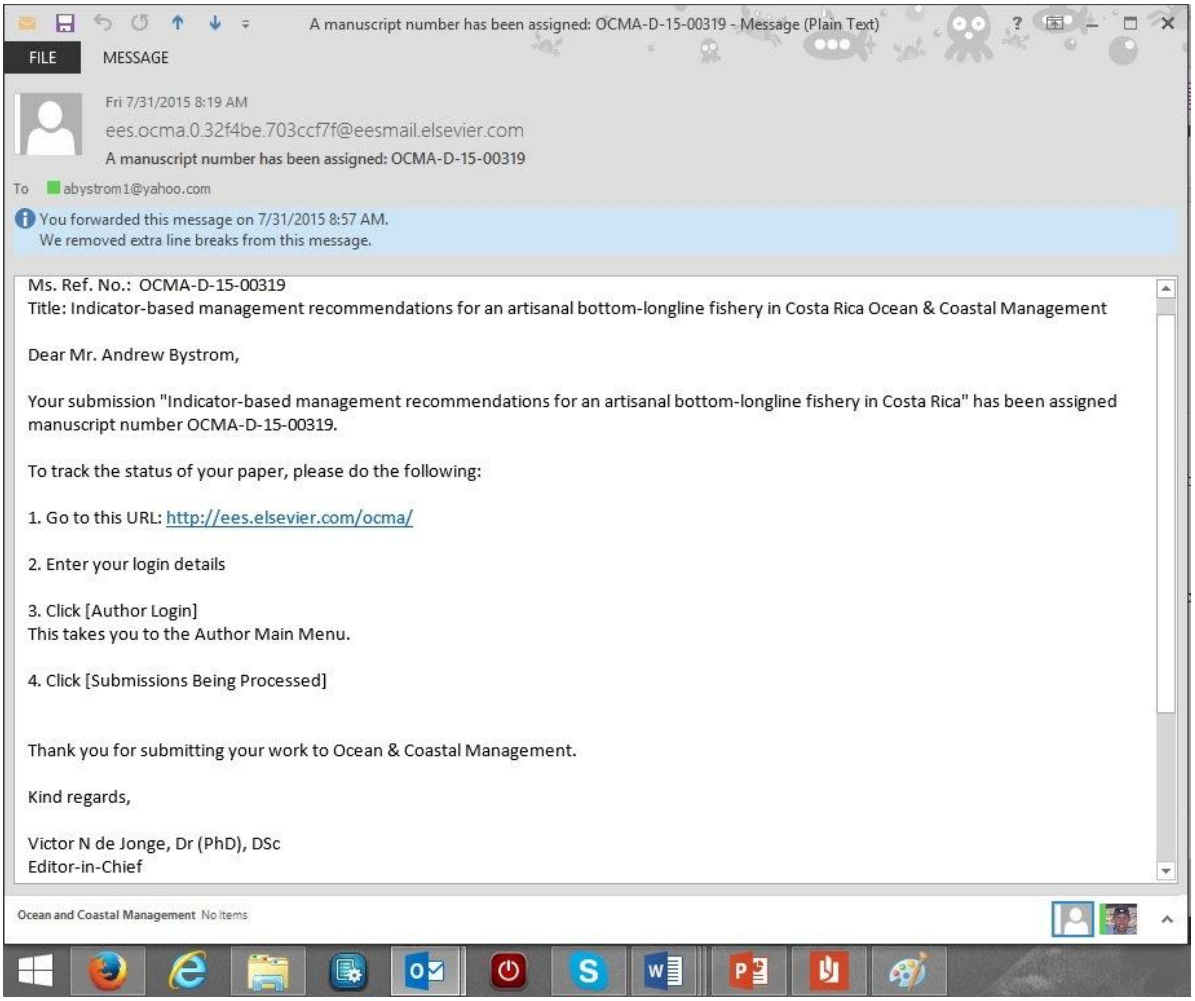

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