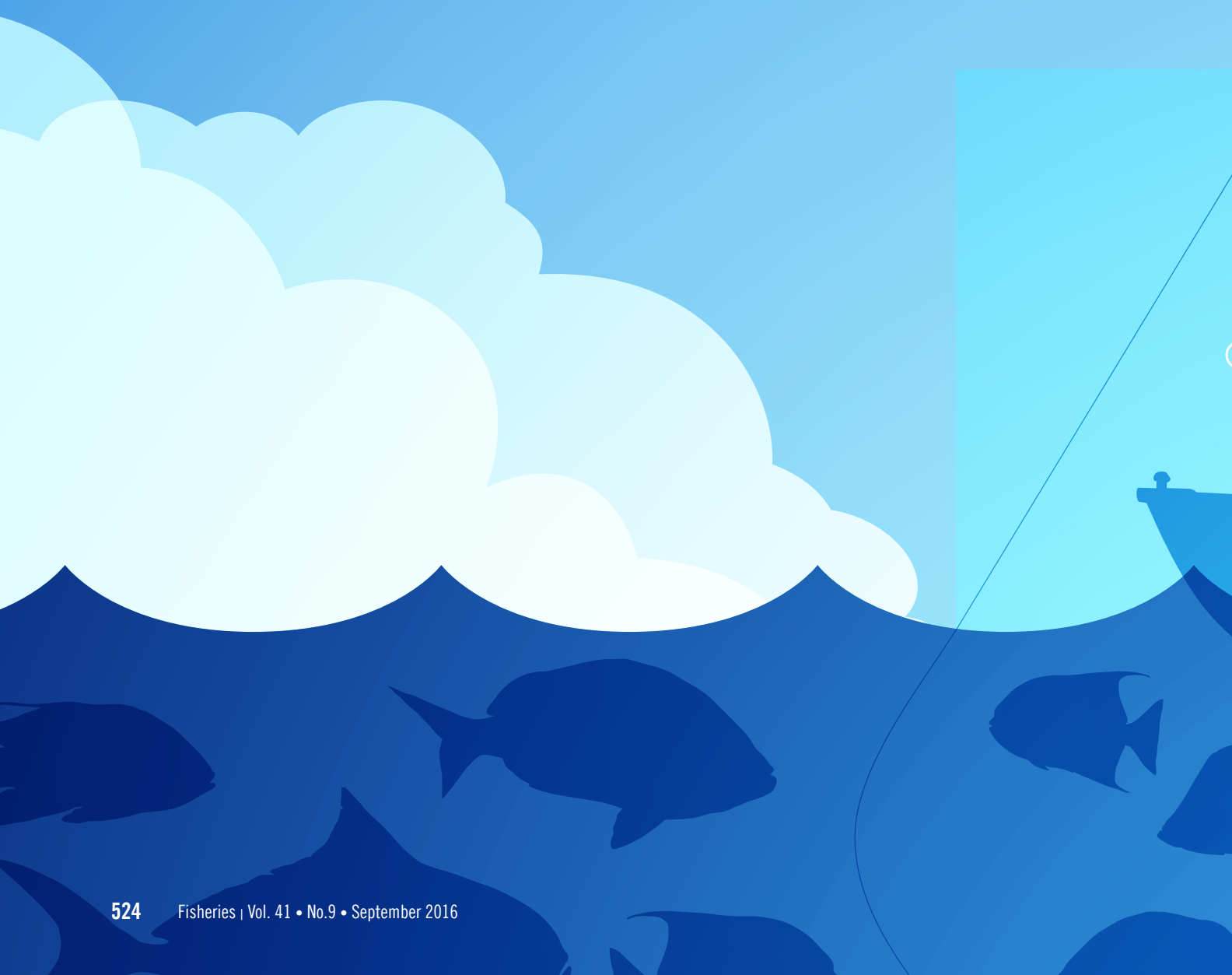


# Understanding and Managing Social–Ecological Feedbacks in Spatially Structured Recreational Fisheries: The Overlooked Behavioral Dimension



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Recreational fisheries are empirically tractable examples of social-ecological systems (SESs) that are characterized by complex interactions and feedbacks ranging from local to regional scales. The feedbacks among the three key compartments of the recreational fisheries SES—individual fish and populations, regionally mobile anglers, and regional and state-level fisheries managers—are strongly driven by behavior, but they are poorly understood. We review and identify factors, antecedents to behaviors, and behaviors most important to the outcomes of the coupled SES of recreational fisheries, which emerge from a range of social-ecological interactions. Using this information, we identify data gaps, suggest how to reduce uncertainty, and improve management advice for recreational fisheries focusing on open-access situations in inland fisheries. We argue that the seemingly micro-scale and local feedbacks between individual fish, fish populations, anglers, and managers lead to the emergence of important macro-scale patterns—some of which may be undesirable, such as regional overfishing. Hence, understanding the scale at which the behavior-mediated mechanisms and processes identified in this article operate is critical for managing for the sustainability of spatially structured recreational fisheries. We conclude our study by providing relevant research stimuli for the future.

## **Comprensión y manejo de la retroalimentación socio-ecológica en pesquerías recreativas espacialmente estructuradas: la dimensión desapercibida del comportamiento**

Las pesquerías recreativas son ejemplos de sistemas socio-ecológicos (SSE) maleables que se caracterizan por poseer interacciones complejas y procesos de retroalimentación que van desde la escala local a la regional. La retroalimentación entre los tres compartimentos principales de los SSE—peces como individuos y poblaciones, pescadores que se mueven en un región determinada y manejadores de pesquerías a nivel estatal—es gobernada por un componente conductual, sin embargo esto no ha sido bien estudiado. Aquí se revisan e identifican los factores, antecedentes del comportamiento y los propios comportamientos más relevantes con respecto al acoplamiento de los SSE en pesquerías recreativas; factores emergen a partir de distintas interacciones socio-ecológicas. Mediante esta información, se identifican huecos de información, se sugiere cómo reducir la incertidumbre y se mejora la asesoría para el manejo de pesquerías recreativas, particularmente en pesquerías continentales de acceso abierto. Se argumenta que la aparente microescala y retroalimentación local entre peces, poblaciones, pescadores y manejadores, dan como resultado importantes patrones de macroescala—algunos de los cuales son indeseables, como la sobrepesca. Por consiguiente, comprender la escala en la cual operan los mecanismos y procesos que controlan el comportamiento identificados en esta contribución, es un aspecto clave para el manejo de la sustentabilidad de las pesquerías recreativas que están espacialmente estructuradas. Se concluye el estudio presentando estímulos para la investigación futura que es relevante en este campo.

## **Comprendre et gérer les commentaires socio écologiques dans le cadre de la pêche récréative spatialement structurée: la dimension comportementale négligée**

La pêche récréative est un exemple de systèmes socio écologiques (SES) qu'il est possible d'exploiter, qui se caractérisent par des interactions et rétroactions complexes allant de l'échelle locale à l'échelle régionale. Les commentaires entre les trois compartiments clés des SES—des différents poissons et des populations, des pêcheurs régionalement mobiles, et des gestionnaires de pêcheries régionales et nationales—sont fortement influencés par les comportements, mais souvent mal compris. Nous passons en revue et identifions les facteurs, antécédents de comportements, et les comportements les plus importants pour les résultats des SES associés de la pêche récréative, émergeant à partir d'une gamme d'interactions socio écologiques. Partant de ces informations, nous identifions les lacunes dans les données, suggérons la façon de réduire l'incertitude, et d'améliorer les conseils de gestion pour la pêche récréative axée sur des situations d'accès libre à la pêche continentale. Nous soutenons que les évaluations apparemment à micro-échelle et locales entre les différents poissons, les populations de poissons, les pêcheurs et les gestionnaires conduisent à l'émergence d'importants modèles à macro-échelle—dont certains peuvent être indésirables, tels que la surpêche régionale. Par conséquent, la compréhension de l'échelle à laquelle les mécanismes et les processus activés par les comportements identifiés dans le présent document opèrent est essentielle pour la gestion de la durabilité de la pêche récréative spatialement structurée. Nous concluons notre étude en fournissant des stimuli de recherche pertinents pour l'avenir.

### **INTRODUCTION**

Recreational fisheries constitute the dominant use of many inland water bodies globally and generate substantial economic, social, and cultural values (Arlinghaus and Cooke 2009). Recreational fisheries can directly impact fish populations, and these impacts can sometimes lead to overharvest or even population collapse (Post et al. 2002). To prevent undesirable outcomes, the actions of anglers are generally constrained by management regulations, which are largely set by governance actors (commonly referred to as “managers”) and further affected by informal norms of proper behavior (Cooke et al. 2013). Recreational fisheries are characterized by complex interactions between people and the natural environment, and hence constitute prime examples of coupled social-ecological systems (SESs; Arlinghaus et al. 2013). Social-ecological systems are defined as unique biogeographical physical units that are linked with, and affected by, associated human actors and institutions (Berkes and Folke 1998; Berkes et al. 2003;

Ostrom 2007, 2009). System outcomes within recreational fisheries, such as regional-level overfishing patterns, strongly depend upon the configuration of interactions, processes, and feedbacks between the three main components of any recreational fishery: individual fish populations (composed of individual fishes), regionally mobile anglers, and regional or state-level managers (Arlinghaus et al. 2013; Hunt et al. 2013).

As coupled SESs, recreational fishery outcomes depend on both states and behaviors of each component—fish, anglers, and managers (Arlinghaus et al. 2013; Fenichel et al. 2013; Hunt et al. 2013). Behavioral processes among anglers and ecosystems can foster biological impacts on fish populations (e.g., declining sizes in catch), which in turn both affect and motivate responses from anglers and managers across spatial scales (Figure 1; Arlinghaus et al. 2013; Hunt et al. 2013). Therefore, the behavioral feedbacks between fish, anglers, and managers must be considered to make reasonable predictions of SES outcomes, which is critical for informing management