Ecological Economics 102 (2014) 118–125

Contents lists available at ScienceDirect

Ecological Economics

journal homepage: www.elsevier.com/locate/ecolecon

Analysis

Adapting to the impacts of global change on an artisanal coral reef fishery

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ARTICLE INFO

Article history:
Received 13 November 2013
Received in revised form 10 March 2014
Accepted 18 March 2014
Available online 27 April 2014

Keywords:
Small-scale fisheries
Fuel price
Wave exposure
Climate change
Emission scenarios
Economic scenarios
Adaptation

ABSTRACT

When assessing future changes in fishing, research has focused on changes in the availability of the resource. Fishers' behaviour, however, also defines fishing activity, and is susceptible not only to changes in weather but also to changes in the economy, which can be faster and more ubiquitous. Using a novel modelling approach and spatially explicit predictors we identified the current drivers of artisanal fishing activity and predicted how it is likely to change in 2025 and 2035 under two climate and two economic scenarios. The model is effective at explaining the activity of fishers (AUC = 0.84) and suggests that economic variables overwhelm the importance of climate variables in influencing the decisions of fishers in our case study area (Utila, Honduras). Although future changes in the overall incidence of fishing activity are modest, decreases in the number of accessible fishing grounds with projected increases in fuel prices will increase localised fishing effort depleting fish resources near the port. Compelling adaptation strategies in the area require the intervention of the market chain to make the sale price of fish more responsive to fuel price fluctuations and changes in fishing behaviour to improve fuel efficiency, including the revival of traditional ways of fishing.

1. Introduction

The artisanal fishing sector provides about 90% of all fishing employment worldwide and nearly 25% of world catches (Schorr, 2005). Artisanal fishing is, however, an economically risky activity, due to high livelihood and income dependency on local resources and the unpredictability of their availability. This makes the activity highly vulnerable to natural fluctuations in fisheries stock, its over-exploitation, and changes in economic drivers such as fuel prices and the supply and price of fish (Allison and Ellis, 2001).

Changes in weather and the economy have the potential to modify fishing activity through changes in the behaviour of fishers and target abundance (Fig. 1). A number of key changes in the Earth's atmosphere and ocean have been detected in recent decades and associated with long-term environmental processes and human-induced factors (Solomon et al., 2007; Tett et al., 1999; Zhang et al., 2007). These include increasing global surface temperature, rising sea levels and changes in precipitation, as well as increases in the variability and intensity of extreme weather events (Emanuel, 2013; Held and Soden, 2006; Solomon et al., 2007). Although research on the effects of climatic change on fisheries is generally focused on the biological system (e.g. Brander, 2007; Cheung et al., 2010), environmental changes are also likely to affect the behaviour of fishers and their access to resources, a consideration that has been consistently neglected in climate change fisheries research (Haynie and Pfeiffer, 2012). Weather variables such as rainfall, strong winds or storms can restrict the number of fishing days (Lopes and Begossi, 2011), and exposure to waves determine accessibility, particularly for small vessels (Bastardie et al., 2013), with areas that are too rough being unsuitable for fishing (Hilborn and Kennedy, 1992).

Climatic change signals are spatially heterogeneous, with some regions showing strong responses and others being almost untouched (Solomon et al., 2007). Future changes in the economy, however, are more ubiquitous (EIA, 2013), and economic constraints have the potential to overwhelm the decisions made by fishers. In selecting a location in which to fish, rational fishers consider not only the catch that they are likely to make, as judged by contemporary information and their own experience, but also the difficulty and costs of fishing under the conditions of a particular day at a particular location. The relevance of economic constraints in the decision-making process of fishers has been considered (e.g. Bastardie et al., 2013; Hilborn and Kennedy, 1992), but projections of economic drivers (e.g. EIA, 2013) have rarely been used when assessing possible changes in fishing activity over time.

Where fisheries research has focused on fishing activity as a function of weather, analyses of the influence of economic drivers had tended to occur separately (Haynie and Pfeiffer, 2012; Johnson et al., 2013; but see Wilen et al., 2002). Here we assess the effects of both drivers on

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http://dx.doi.org/10.1016/j.ecolecon.2014.03.010
0921-8009/

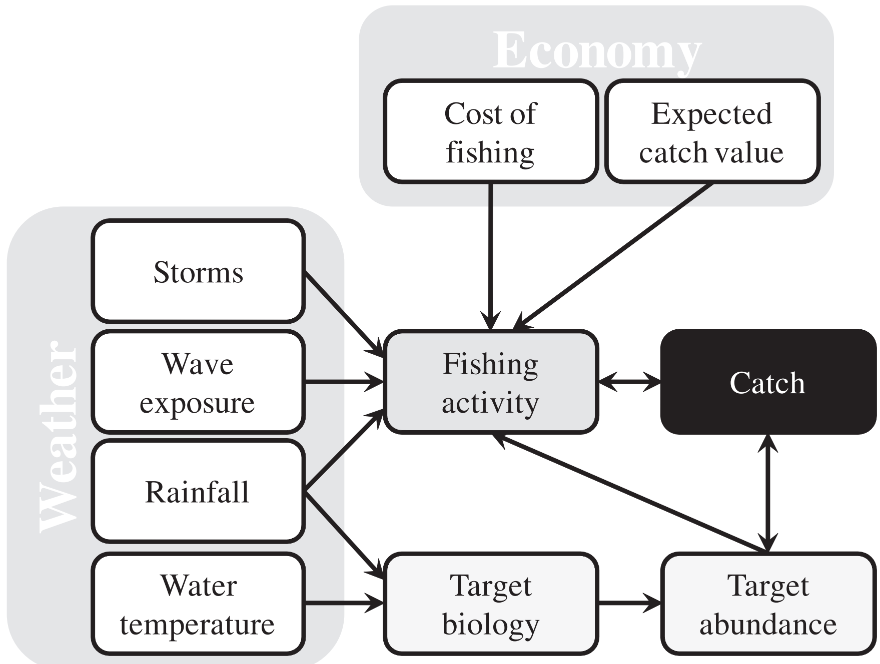

Fig. 1. Conceptual model of linkages between weather and economic drivers of fishing activity, target biology and ultimately fishing catches.

artisanal fishing activity simultaneously, and predict future changes under different climate and economic scenarios. The novelty of this research includes: (1) the spatially-explicit quantification of wave exposure, which restricts fishing access; (2) the use of a novel modelling approach (MaxtEnt, a presence-only model) because of the occurrence of unreliable zeros in our dataset, which is a common problem in fisheries data; (3) the use of downscaled climate change models to forecast region-specific weather changes; and (4) the use of economic models to forecast changes in fishing costs. We apply the model to an artisanal fishery on the island of Utila in the Bay Islands (Honduras), where weather seems to be particularly relevant in shaping fishing activity. By understanding current drivers of fishing activity and how these are likely to change in the future, we hope to gain insight into how fisheries are likely to change and provide advice on building adaptive capacity in this vulnerable system.

2. Material and Methods

2.1. Study Area

This study was carried out in Utila, Bay Islands, in the Honduran Caribbean (Fig. 2). The Bay Islands have a tropical climate with a wet season that runs from October to January, an average monthly rainfall maximum of about 10.44 mm day^{-1}, and daily maximum rainfall reaching up to 22.8 mm day^{-1}. Winds come from the east with a mean direction of $75.5 \pm 51.7°$, at an average speed of 4.6 ± 2.4 ms^{-1} (average and standard deviation, inset in Fig. 2). There are no large seasonal shifts in wind conditions though winds are weaker between September and January. Wave exposure closely follows the wind patterns. The eastern (windward) side of the islands is heavily exposed, while the west (leeward) side is generally protected from the action of wind-induced waves (Fig. 2).

Artisanal fishers in Utila can access four distinct fisheries including hand-lining for coral reef associated fin fish or deep shelf snapper species, trolling for pelagic fish species or the collection of lobster and conch using SCUBA equipment. The fishing community that populates two small cays southwest of Utila is the most active in the Bay Islands, most heavily reliant on fishing (60% of the households are directly reliant on fishing: Box and Canty, 2010) and fish over the largest area (Gobert et al., 2005). Fishers use small boats (up to 38 ft) with inboard diesel engines of about 15–70 horse power (pers. obs). Hand lines are the dominant fishing gear, but fishers might also use traps to target grouper (Serranidae) spawning aggregations and occasionally mesh nets when king mackerel (*Scomberomorus cavalla*) migrate close to the island. Shallow, coral reef associated fish species are the most important targets for the hand-line fishery, with the main species being yellowtail snapper (*Ocyurus chrysurus*), accounting for 36% (by weight) of the total landed catch (Box and Canty, 2010). Fisheries in Utila work on a share system: the fishers are not paid a wage but instead they receive a share of the profit after the costs of fuel, bait and ice have been deducted from the total catch revenue. Boats normally have two fishers who work together for a common catch. The skipper receives 35% of the profit while the second man receives 30%. The owner of the fishing boat receives 35% of the profit and is responsible for the maintenance of the vessel. Owners may skipper their own vessel or lease their boat to a different skipper under this payment system. If there is no catch fishing, it is the responsibility of the skipper to cover the fishing costs. Additional fishers may join a fishing pair under a separate fishing agreement. Additional fishers contribute around 1/5 of the total fuel costs and provide their own ice, bait and tackle. They keep their catch separate to the main fishing pair and on returning to port give half of their total catch to the skipper as payment. Fuel comprises about 75% of the operating costs of the trip, with average fuel consumption in the order of 4 gal of diesel at about USD 14.72 in 2010. Although the fishery involves few associated operating costs, they take about 50% of the gross revenue of the boat in an average trip. As a result, the fishery relies in high yield events of spawning aggregations or migrations to elevate the income (Box and Canty, 2010).

The Honduran government's capacity for monitoring, control and surveillance of the artisanal fishery is weak. Artisanal fishing vessels, classified as those under three metric tonnes, are required to be centrally registered and licenced annually, as are artisanal fishers. These prerequisites for fishing are poorly enforced. There are no regulations controlling the minimum size for fin fish caught by artisanal fishers and no limits on catch or effort. Species-specific protection is afforded only to Nassau grouper (*Epinephelus striatus*) at their seasonal spawning aggregations and the retention and sale of all shark species are prohibited. Regulations exist which prohibit the use of poisons,