Deep–Sea Research Part II xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Deep–Sea Research II

journal homepage: www.elsevier.com/locate/dsr2

Seasonal forecasting of dolphinfish distribution in eastern Australia to aid recreational fishers and managers

Stephanie Brodie[a,b,*], Alistair J. Hobday[c], James A. Smith[a,b], Claire M. Spillman[d], Jason R. Hartog[c], Jason D. Everett[a,b], Matthew D. Taylor[a,e], Charles A. Gray[a,f], Iain M. Suthers[a,b]

[a] Evolution and Ecology Research Centre, School of Biological, Earth and Environmental Sciences, University of New South Wales, Sydney, NSW 2052, Australia
[b] Sydney Institute of Marine Science, Mosman, NSW 2028, Australia
[c] Oceans and Atmosphere, Commonwealth Scientific and Industrial Research Organisation, GPO Box 1538, Hobart 7001, Australia
[d] Bureau of Meteorology, GPO Box 1289, Melbourne, VIC 3001, Australia
[e] New South Wales Department of Primary Industries, Port Stephens Fisheries Institute, Locked Bag 1, Nelson Bay, NSW 2315, Australia
[f] WildFish Research, Grays Point, NSW 2232, Australia

ARTICLE INFO

Keywords:
Seasonal forecast
Species distribution
Habitat model
Management
Recreational fishing
POAMA

ABSTRACT

Seasonal forecasting of environmental conditions and marine species distribution has been used as a decision support tool in commercial and aquaculture fisheries. These tools may also be applicable to species targeted by the recreational fisheries sector, a sector that is increasing its use of marine resources, and making important economic and social contributions to coastal communities around the world. Here, a seasonal forecast of the habitat and density of dolphinfish (*Coryphaena hippurus*), based on sea surface temperatures, was developed for the east coast of New South Wales (NSW), Australia. Two prototype forecast products were created; geographic spatial forecasts of dolphinfish habitat and a latitudinal summary identifying the location of fish density peaks. The less detailed latitudinal summary was created to limit the resolution of habitat information to prevent potential resource over-exploitation by fishers in the absence of total catch controls. The forecast dolphinfish habitat model was accurate at the start of the annual dolphinfish migration in NSW (December) but other months (January - May) showed poor performance due to spatial and temporal variability in the catch data used in model validation. Habitat forecasts for December were useful up to five months ahead, with performance decreasing as forecast were made further into the future. The continued development and sound application of seasonal forecasts will help fishery industries cope with future uncertainty and promote dynamic and sustainable marine resource management.

1. Introduction

Changes in climate are expected to continue to alter the distributions of marine species, particularly pelagic species that are associated with specific water masses (Lehodey et al., 2013; Cheung et al., 2015). Describing the projected distributions of these marine species can inform industry and communities of potential changes to ecosystem services (such as fishing) and help facilitate human adaptation to both climate variability and long-term change (Allison et al., 2009). Long-term climate forecasts have predicted large-scale global spatial changes to marine biodiversity (e.g. Cheung et al., 2009; Brander, 2010; Barange et al., 2014). However, these long-term timescales are seen as less relevant to fishing industries and communities whose business and management decisions (i.e. local weather, labour costs, market fluctuations, policy) are based on shorter timescales (Hobday et al., 2016). In response to this need, seasonal forecasts of environmental conditions have become an important tool in assisting decision making on timescales of weeks to months in several Australian seafood sectors (Hobday et al., 2016).

In recent years, seasonal forecast products based on environmental variables have been developed to aid commercial tuna fisheries (Hobday et al., 2011; Eveson et al., 2015) and aquaculture operations (Spillman and Hobday, 2014; Spillman et al., 2015). Forecasts of environmental variables are generated from seasonal prediction systems, such as the Australian Bureau of Meteorology's global ocean-atmosphere ensemble model POAMA (Predictive Ocean Atmosphere

* Corresponding author at: Evolution and Ecology Research Centre, School of Biological, Earth and Environmental Sciences, University of New South Wales, Sydney, NSW 2052, Australia.
E-mail address: stephanie.brodie@unsw.edu.au (S. Brodie).

http://dx.doi.org/10.1016/j.dsr2.2017.03.004

Please cite this article as: Brodie, S., Deep–Sea Research Part II (2017), http://dx.doi.org/10.1016/j.dsr2.2017.03.004

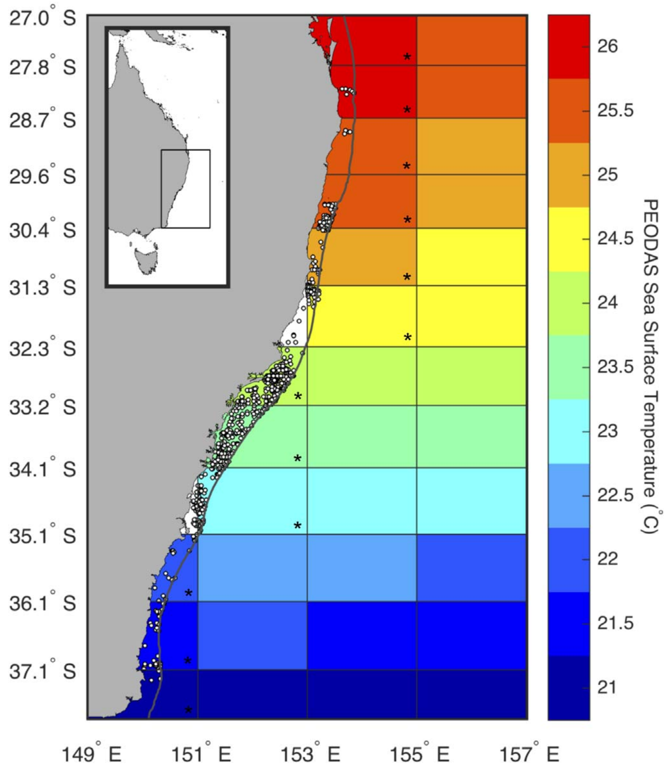

Fig. 1. Map of the east coast of Australia (inset) indicating the NSW coastline. Circles indicate dolphinfish catch data for the period of 1994–2012 (n=1720), with the grey line showing the 200 m isobath. Colours and colour scale are the PEODAS SST annual climatology (SST_C; °C; 1994–2010). The SST_C grid resolution (~1° latitude×2° longitude) is the same as POAMA forecast SST (SST_F). Stars indicate the grid cells used in the dolphinfish habitat forecast.

Model for Australia POAMA) (e.g. Spillman et al., 2011). The application of such seasonal forecasting tools to fishery industries has gained momentum in recent years (Tommasi et al., in press), however, to date there has not been any application to the recreational fisheries sector, despite their increasing use of marine resources (Henry and Lyle, 2003; Zischke et al., 2012).

The recreational fishing sector makes significant economic and social contributions to local communities (Henry and Lyle, 2003; Brownscombe et al., 2014). In Australia, 19.5% of people fish recreationally, resulting in a national annual effort of 20.6 million fisher days, and an economic expenditure of $1.86 billion (2000–2001; Henry and Lyle, 2003). The state of New South Wales (NSW; Fig. 1) accounts for ~30% of the Australian recreational fisher population (Henry and Lyle, 2003), and in this state a number of government programs exist to enhance recreational fishing (e.g. via fish aggregation devices and artificial reefs) and encourage participation in fisheries management and conservation (e.g. game fish tagging program, and catch-and-release fishing).

Within the recreational fishing sector there are a number of end users that could benefit from forecasts at seasonal timescales. One example is NSW Department of Primary Industries (DPI) fisheries enhancement program that seasonally deploys anchored fish aggregation devices (FADs) along a ~1000 km coastline to provide enhanced fishing opportunities for recreational anglers. Seasonal forecasts may assist decision-making regarding the location, density, and deployment duration of individual FADs. Another recreational end user that could benefit from seasonal forecasts is the charter boat fishing industry. In NSW, 127 charter boats conduct game fishing and/or deep-sea bottom fishing operations (2015; NSW DPI), and seasonal forecasting tools could support decisions on future boat maintenance scheduling and advertising for seasonal fishing opportunities.

Seasonal forecast products for fisheries must convey an appropriate but useful amount of information to the target user group, without risking the potential over-exploitation of a species. The outputs of seasonal forecasts are often provided in map form, however, output presentation can be modified for different user groups (Hobday et al., 2016). For example, a high resolution map of predicted fish density and distribution may be useful for commercial fisheries where quota limits exist, but this resolution may not be desirable for recreational anglers where total catch is often not regulated. Instead, a habitat description that communicates a more simplistic summary of predicted fish distributions may be more appropriate. This approach has been implemented in quota-managed commercial southern bluefin tuna fisheries off the east coast of Australia, where forecast maps provide three levels of fish probability to manage the spatial distribution of fishing effort (Hobday et al., 2011).

The goal of this study was to develop and assess a seasonal forecast product of fish distributions for the recreational fisheries sector. The prototype product was developed for an epi-pelagic predator, dolphinfish (*Coryphaena hippurus*), which is strongly associated with warm water and other oceanographic features (Kingsford and DeFries, 1999; Brodie et al., 2015). The study region was the oceanographically dynamic offshore waters of NSW, which is dominated by the East Australia Current (EAC; Fig. 1). In this region dolphinfish are a major recreational species commonly targeted in catch-and-release fishing. The offshore distribution and high recreational catch rates of dolphinfish in NSW offer the opportunity to use the habitat preference model described in Brodie et al. (2015) to develop a seasonal habitat forecast.

2. Material and methods

2.1. Dolphinfish habitat model

A dolphinfish habitat model was developed using the methods described in Brodie et al. (2015). Here, the habitat model was designed to forecast fish distributions based on ocean conditions, and for simplicity sea surface temperature (SST) was the main variable used as provided by the seasonal prediction system POAMA. Species location data, termed presence data, for dolphinfish were obtained from a cooperative recreational fisheries catch-and-release program facilitated by NSW DPI. These data consist of angler-recorded coordinate locations (Fig. 1) and times (Fig. 2) of fish capture but no

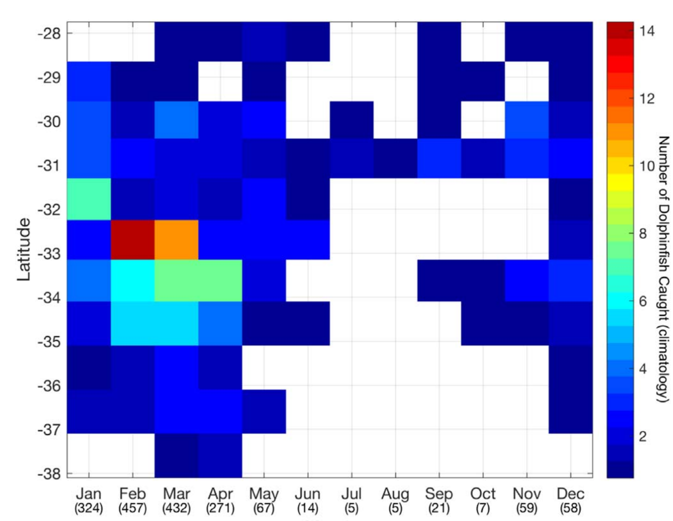

Fig. 2. Climatology (1994–2012) of the number of dolphinfish caught, as indicated by the colour scale, for each month and latitude in the study region. Numbers in brackets on x-axis indicate the total catch of dolphinfish for all years in each month. The grid resolution of latitude (~1°) is the same as the POAMA forecast ocean grid resolution (~1° latitude×2° longitude).