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Review

Predicting environmental drivers for prawn aquaculture production to aid improved farm management

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ABSTRACT

A wide range of aquaculture industries are exposed to environmental conditions and variability which can impact on production. Information about future climate conditions on a range of time scales can improve risk management, buffer production against unfavourable environmental conditions, and allow maximised production during opportune times. Seasonal forecasting, providing information beyond weather forecasting up to several months into the future, can aid such decision making. In north-east Australian coastal pond-based prawn farms environmental stresses influence timing of farming periods, animal growth and survival. Here we describe the development, packaging and provision of regional and local forecast products, derived from the Predictive Ocean Atmosphere Model for Australia (POAMA; version 2), to the Queensland prawn industry. Product development followed a three-stage process; (i) assessment of management needs and critical timescales, (ii) development and evaluation of the forecast products, and (iii) forecast implementation and refinement of the forecast products. Prawn farm managers identified the critical forecast variables as minimum and maximum air temperatures and rainfall at lead times of up to 2–3 months. The POAMA forecast skill for all three variables was evaluated, with three spatially averaged regional environmental indexes derived from POAMA showing a strong relationship with large-scale observed conditions. Forecast accuracy was assessed using model hindcast data together with historical observations, and was similar in all three regions, higher for temperature than rainfall, and declined with lead time in all cases. Forecast indices were then scaled using local weather station information for a subset of prawn farms in the study. Discussion with prawn farm managers helped refine the format and visualisation of the forecasts. Tailored forecast packages were then delivered through a web-based system and directly by email. These forecasts could aid a range of management decisions, and user feedback led to further refinement. This approach has great potential to be extended to other coastal aquaculture industries using these and other environmental variables. Information about future conditions, such as provided by seasonal forecasting, can assist aquaculture managers in development of production plans that will be more robust to short-term environmental variability and represents the first adaptation step on a pathway to coping with longer term climate change.

Contents

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1. Introduction

Aquaculture, marine and freshwater, is the fastest growing of the animal protein production systems since the 1970s (~8% per annum) (FAO, 2010; Merino et al., 2012). Both sea-cage and pond-based aquaculture industries are exposed to environmental conditions during at least part of the growing cycle, and as such, production can be impacted by variability in these conditions (Bell et al., 2011). The most dramatic examples of these impacts are extreme events such as floods, storms and tropical cyclones, however anomalously warm or cool temperatures can also result in lost production and income (Spillman and Hobday, 2014). Information about future environmental conditions on a range of time scales can improve risk management, buffer production against unfavourable environmental conditions, and allow maximised production during opportune times (Hobday et al., 2008, in press; Bell et al., 2013).

Weather forecasting at time scales up to one week ahead is suited to short-term decision making and is heavily utilised by many aquaculture industries. However many strategic management decisions related to environmental variability, such as the timing of seeding and harvesting, require longer lead times of weeks to months (Spillman et al., 2011; Hobday et al., in press). Seasonal and subseasonal forecasting, i.e. beyond a week and out to a season, can provide environmental information at these timescales, offering new opportunities for improved and proactive management. Dynamical seasonal forecasting has delivered both operational and prototype projections up to several months into the future for a number of marine industries in Australia including wild southern blue fin tuna fisheries on the east coast of Australia (Hobday et al., 2011), Tasmanian salmon aquaculture (Spillman and Hobday, 2014) and coral reef management (Spillman, 2011). These cutting edge applications span offshore waters to coastal situations, with each requiring tailoring to the climate variables, timescales and system of interest. The success of these applications has generated interest in other aquaculture and marine industries including the prawn aquaculture industry in north-east Australia.

In Australia, pond-based prawn aquaculture is located predominately in a narrow strip in Queensland on the north-east coast (Fig. 1). Prawn consumption and demand in Australia typically peaks in the holiday seasons of Christmas and Easter. The Australian prawn industry total production was around 2900 tonnes in 2011–12 (valued at AUD$59 million), with more than 95% of the volume and value from Queensland farms (ABARES, 2013). Tiger prawns (*Penaeus monodon; also recognised as Penaeus esculentus and Penaeus semisulcatus*) are the main species, with banana prawns (*Fenneropenaeus merguiensis*) a secondary species. Commercial prawn farms consist of between 10 and 100 shallow ponds (~1.5 m deep) each approximately 1 ha in size. The growing season is constrained by minimum temperatures when prawn larvae are introduced to ponds and the desired size at harvest time. Water temperatures above 22 °C are considered suitable for stocking ponds, with optimal growth achieved at temperatures of 30–34 °C and salinity of around 25 psu, although a wide range of salinities can be tolerated (Deering et al., 1995; Jackson and Wang, 1998). Many farms have hatcheries for larval production or buy in brood stock from local producers, while others collect wild broodstock from nearby ocean regions. Both species grow from larvae to harvestable size in around 18–28 weeks, depending on pond conditions. The length of the growing season varies with latitude; prawn farms in the far north can often achieve two harvests per year, as the winter water temperatures are milder, while in the south where the winter is cooler, only one harvest can be achieved.

The industry is vulnerable to extremes in temperature and rainfall as well as tropical cyclones. Farms are typically located near a tidal inlet or creek for water supply access for pond flushing and filling to facilitate salinity control. Heavy rainfall can reduce the quality of water supplies to the farm, particularly the first seasonal pulse of heavy falls which flush the catchment and can render the farm water supply unusable due to such inputs as herbicides, clay particles and harmful algal species. Heavy rainfall can also wash out roads and prevent supplies from reaching remote farms, and lower salinity below optimal levels. Temperature influences the growth of prawns (Deering et al., 1995; Jackson and Wang, 1998) and thus the timing of harvest, which is critical to delivering supply for peak market opportunities and thus farm cash flow. Tropical cyclones can result in loss of road access to farms, destruction of farm infrastructure such as sheds, generators and aerators, and loss of power (Hobday et al., 2012).

Recent extreme flooding, heavy rain, and cyclone activity has impacted the prawn industry, as well as other fishing and aquaculture businesses, in north-east Australia (Marshall et al., 2013a,b). These events have focused attention on development of strategies to reduce the impact of climate extremes on industries as well as better management under more typical climate variability. If businesses had been provided with subseasonal–seasonal forecast products indicating the probability of extreme conditions in the upcoming weeks and months, management strategies may have been able to be implemented in advance, potentially reducing losses. A 12 month pilot study to develop, assess and implement prototype subseasonal–seasonal forecast products for Queensland prawn farms, funded by the Queensland Government Cyclone Yasi Recovery Fund and supported by the Australian Prawn Farmers Association, was performed in 2011–12 to address this need and is described here. The forecasts are from the Australian Bureau of Meteorology's dynamical forecast system, POAMA (Predictive Ocean Atmosphere Model for Australia; Hudson et al., 2013).

Development of prototype subseasonal–seasonal forecasting tools for the prawn industry follows the three-stage process outlined in Hobday et al. (in press). As detailed below, the first step is to define and assess the needs of end users, determining the critical environmental variables, and collating any farm data from the users that will inform forecast product development. The second step is to develop the forecast products, including forecast skill assessment and packaging of products for the end user. Implementation is the final step, and involves forecast delivery, education and support of end users in forecast interpretation, and refinement of the forecast products, based on user feedback.

2. Step 1: assess industry needs

Initial discussions took place with industry representatives at a range of meetings, resulting in the co-drafting of research proposals to investigate the application of seasonal forecasts; a project was subsequently funded. In discussion with the primary industry body, the Australian Prawn Farmers Association, we scoped forecast options and selected eight representative farms of the 32 spanning the Queensland production region. The project team met onsite with farm managers at