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**ÍNDICE**

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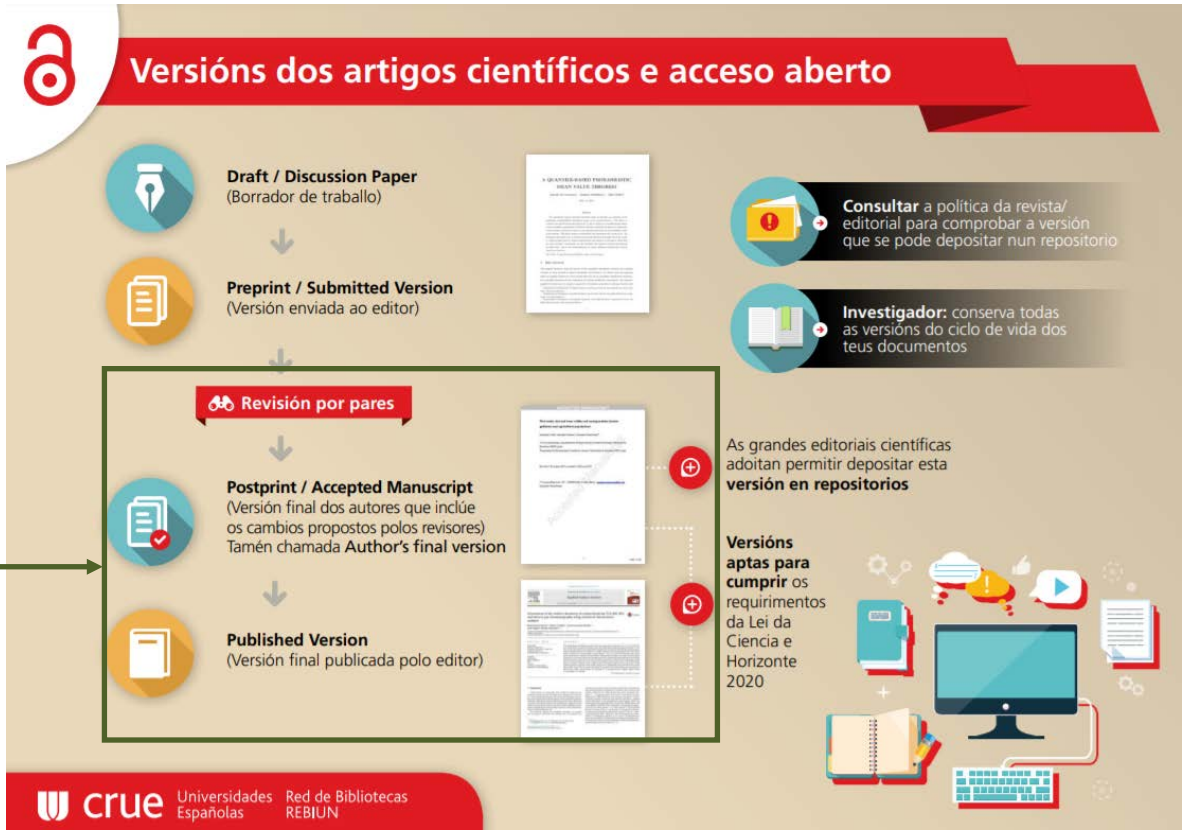


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## POST-PRINT DO AUTOR/A EXEMPLOS ACEPTADOS:

# A dynamic economic equilibrium model for the economic assessment of the fishery stock-rebuilding policies

José-María Da-Rocha U.Vigo[†]
Raul Prellezo AZTI[‡]
Jaume Sempere El Colegio de México[§]
Luís Taboada Antelo (IIM) CSIC ¶

February 2019

ABSTRACT

The paper develops and analyses a dynamic general equilibrium model with heterogeneous agents that can be used for assessment of the economic consequences of fish stock-rebuilding policies within the EU. In the model, entry and exit processes for individual plants (vessels) are endogenous, as well as output, employment and wages. This model is applied to a fishery of the Mediterranean Sea. The results provide both individual and aggregate data that can help managers in understanding the economic consequences of rebuilding strategies. In particular, this study shows that, for the application presented, all aggregate results improve if the stock rebuilding strategy is followed, while individual results depend on the indicator selected.

Keywords: Macroeconomics; General equilibrium model; Multiannual management plans.
JEL codes: Q22

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# Monopile-mounted Wave Energy Converter for a Hybrid Wind-Wave System

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**Abstract:**

Multipurpose platforms are innovative solutions to combine the sustainable exploitation of multiple marine resources. Among them, hybrid wind-wave systems stand out due to the multiple synergies between these two forms of marine renewable energy. The objective of this work is to develop a hybrid system for monopile substructures, which are currently the prevailing type of substructure for offshore wind turbines, and more specifically to focus on the wave energy converter sub-system, which consists in an oscillating water column. For this purpose, an in-depth experimental campaign was carried out using a 1:40 scale model of the wave energy converter sub-system and the monopile substructure, considering regular and irregular waves. Based on the experimental results the performance of the device and its interaction with the wave field were characterised – a fundamental step to fully understand the benefits and limitations of this hybrid wind-wave system, which sets the basis for its future development. Regarding the performance, the best efficiency was obtained with the turbine damping corresponding to a 0.5% orifice size, and two resonance peaks were identified ($T = 9$ and 6 s). As for the interaction of the hybrid system with the wave field, between 5% and 66% of the incident wave power is reflected and between 3% and 45%, transmitted. The wave period was found to be the parameter that most influenced wave run-up on the substructure. This characterisation of the behaviour of the hybrid system shows that it is indeed a promising option for further development.

**Keywords:** Hybrid wind-wave; Wave energy, Offshore Wind; OWC; Physical modelling





**Analysis of the impact of different operating conditions on the performance of a reversible heat pump with domestic hot water production**

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**ABSTRACT**

This paper presents the mathematical modelling of a liquid-to-water heat pump with scroll compressor, brazed plate heat exchangers, additionally built-in liquid-vapor heat exchanger (LVHX) and a desuperheater for domestic hot water (DHW) production. The refrigerant is the zeotropic mixture R407C and the liquid used in the outdoor loop is a propylene-glycol water mixture. Developed mathematical model is validated on experimental data and used as a tool for the heat pump analysis. Simulation results are obtained for the effect of the degree of superheat at the evaporator outlet, the subcooling degree at the condenser outlet, the effect of using or not the LVHX and the effect of using or not the desuperheater for DHW for typical operating conditions of liquid-to-water heat pumps (EN-14511-2, 2011) in the cooling and

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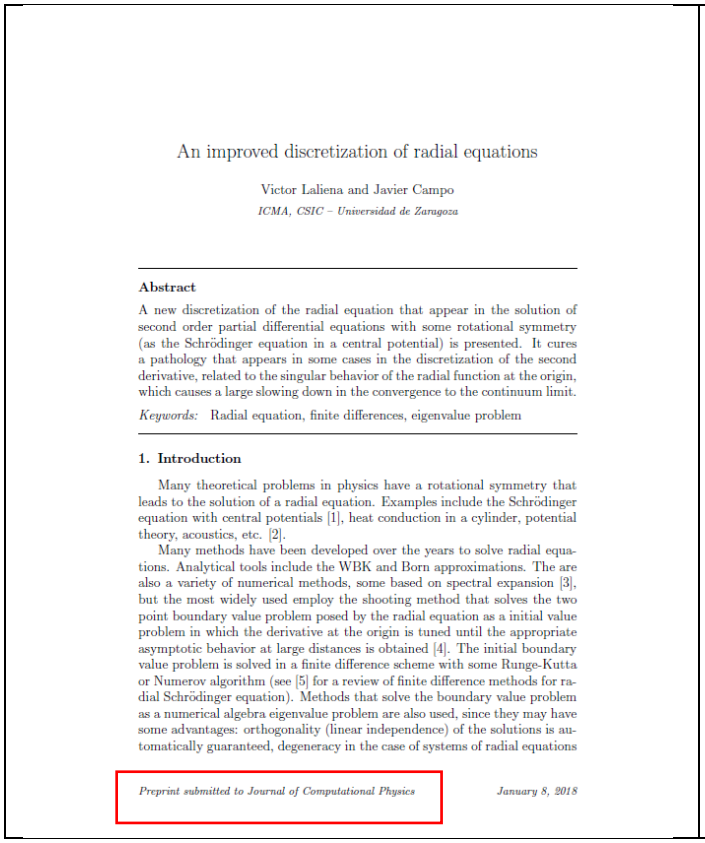

An improved discretization of radial equations

Victor Laliena and Javier Campo

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**Abstract**

A new discretization of the radial equation that appear in the solution of second order partial differential equations with some rotational symmetry (as the Schrödinger equation in a central potential) is presented. It cures a pathology that appears in some cases in the discretization of the second derivative, related to the singular behavior of the radial function at the origin, which causes a large slowing down in the convergence to the continuum limit.

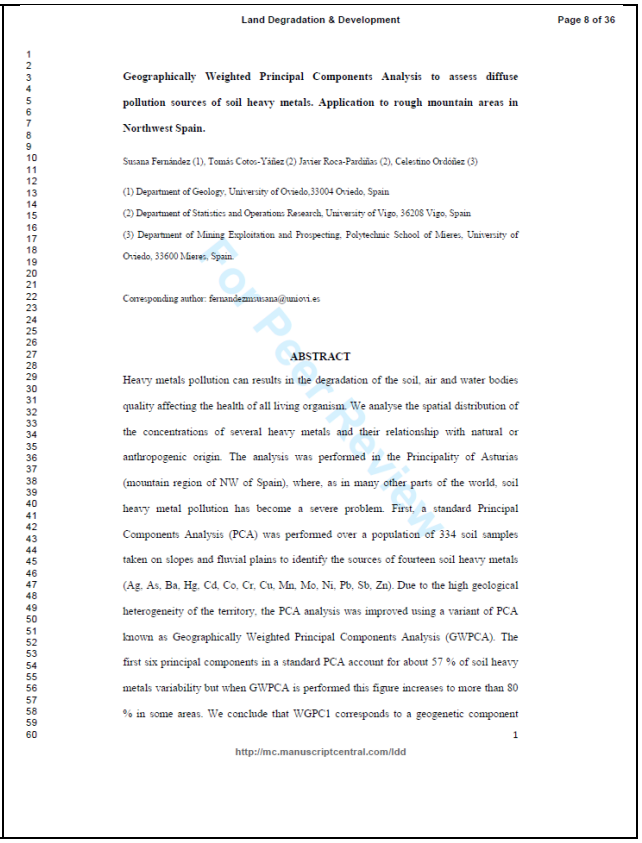
*Keywords:* Radial equation, finite differences, eigenvalue problem

**1. Introduction**

Many theoretical problems in physics have a rotational symmetry that leads to the solution of a radial equation. Examples include the Schrödinger equation with central potentials [1], heat conduction in a cylinder, potential theory, acoustics, etc. [2].

Many methods have been developed over the years to solve radial equations. Analytical tools include the WBK and Born approximations. The are also a variety of numerical methods, some based on spectral expansion [3], but the most widely used employ the shooting method that solves the two point boundary value problem posed by the radial equation as a initial value problem in which the derivative at the origin is tuned until the appropriate asymptotic behavior at large distances is obtained [4]. The initial boundary value problem is solved in a finite difference scheme with some Runge-Kutta or Numerov algorithm (see [5] for a review of finite difference methods for radial Schrödinger equation). Methods that solve the boundary value problem as a numerical algebra eigenvalue problem are also used, since they may have some advantages: orthogonality (linear independence) of the solutions is automatically guaranteed, degeneracy in the case of systems of radial equations

*Preprint submitted to Journal of Computational Physics* *January 8, 2018*





**Geographically Weighted Principal Components Analysis to assess diffuse pollution sources of soil heavy metals. Application to rough mountain areas in Northwest Spain.**

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**ABSTRACT**

Heavy metals pollution can results in the degradation of the soil, air and water bodies quality affecting the health of all living organism. We analyse the spatial distribution of the concentrations of several heavy metals and their relationship with natural or anthropogenic origin. The analysis was performed in the Principality of Asturias (mountain region of NW of Spain), where, as in many other parts of the world, soil heavy metal pollution has become a severe problem. First, a standard Principal Components Analysis (PCA) was performed over a population of 334 soil samples taken on slopes and fluvial plains to identify the sources of fourteen soil heavy metals (Ag, As, Ba, Hg, Cd, Co, Cr, Cu, Mn, Mo, Ni, Pb, Sb, Zn). Due to the high geological heterogeneity of the territory, the PCA analysis was improved using a variant of PCA known as Geographically Weighted Principal Components Analysis (GWPCA). The first six principal components in a standard PCA account for about 57 % of soil heavy metals variability but when GWPCA is performed this figure increases to more than 80 % in some areas. We conclude that WGPC1 corresponds to a geogenetic component

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# Assessing Significance in High-Throughput Experiments by Sequential Goodness of Fit and *q*-Value Estimation

**Antonio Carvajal-Rodriguez[1]*, Jacobo de Uña-Alvarez[2]**

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**Abstract**

We developed a new multiple hypothesis testing adjustment called SGoF+ implemented as a sequential goodness of fit metatest which is a modification of a previous algorithm, SGoF, taking advantage of the information of the distribution of *p*-values in order to fix the rejection region. The new method uses a discriminant rule based on the maximum distance between the uniform distribution of *p*-values and the observed one, to set the null for a binomial test. This new approach shows a better power/pFDR ratio than SGoF. In fact SGoF+ automatically sets the threshold leading to the maximum power and the minimum false non-discovery rate inside the SGoF family of algorithms. Additionally, we suggest combining the information provided by SGoF+ with the estimate of the FDR that has been committed when rejecting a given set of nulls. We study different positive false discovery rate, pFDR, estimation methods to combine *q*-value estimates jointly with the information provided by the SGoF+ method. Simulations suggest that the combination of SGoF+ metatest with the *q*-value information is an interesting strategy to deal with multiple testing issues. These techniques are provided in the latest version of the SGoF+ software freely available at http://webs.uvigo.es/acraaj/SGoF.htm.

**Citation:** Carvajal-Rodriguez A, de Uña-Alvarez J (2011) Assessing Significance in High-Throughput Experiments by Sequential Goodness of Fit and *q*-Value Estimation. PLoS ONE 6(9): e24700. doi:10.1371/journal.pone.0024700

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**Competing Interests:** The authors have declared that no competing interests exist.

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## Introduction

Multiple hypothesis testing has become an important issue since the advent of "omic" technologies: genomics, proteomics, transcriptomics etc. Usually it involves the simultaneous testing of thousands of hypotheses producing a set of significant *p*-values. The later may be indicating some kind of true effect for each test. By true effect we mean, depending on the kind of experiments, an increased expression of a gene, or quantity of RNA, protein and so on. There are several methods controlling the family wise error rate (FWER) with the aim to minimize the type I error, i.e. the problem of detecting effects which are not true ones. Unfortunately, minimizing type I error increases type II error, that is, diminishes the statistical power to detect true effects. An interesting alternative is to control the false discovery rate, FDR [1], which is the expected proportion of false discoveries among the total ones i.e. the expected proportion of the rejected null hypotheses which are erroneously rejected. When computing the FDR, two strategies can be followed [2,3]. First, fixing an FDR level of acceptance, say 5%, and then detecting the rejection region of interest i.e. the widest region with associated FDR below the fixed level. The second strategy has been proposed by Storey and Tibshirani [4] and aims to fix the rejection region and then to estimate the FDR over that region. This strategy also provides the estimation of the *q*-values linked to each test, i.e. the expected proportion of false positives incurred if we call a given test significant [2]. However, the use of the *q*-values does not provide an automatic procedure to detect true effects while informing about the probability of committing a false discovery. The computation of *q*-values implies a previous estimation of the fraction of tests with true null distribution [4]. It is worth mentioning that the so called pFDR, i.e. FDR conditional upon having rejected one or more hypotheses, can not be controlled when the probability of having an effect is low [2,5] or even when the *p*-values are obtained from low-sample size tests [6]. The above problems are still more serious when considering that, under realistic sample sizes, the FDR controlling methods increase type II error if the number of tests is high and the size of the effects are weak i.e. the higher the number of tests the lower the power to detect true effects [6].

The obvious goal when performing multiple testing adjustments is to detect as many true positives as possible while maintaining the false ones below a desired threshold. Therefore, for a fixed percentage of existing effects, the higher the number of tests performed, the higher the number of true positives that should be detected. In a previous work [6] we have proposed an exact binomial meta-test as a new multiple testing adjustment which holds the desirable property of increasing power with the number of tests. The binomial meta-test compares the observed and expected proportions of *p*-values falling below threshold $\gamma$ (often $\gamma = 0.05$) and makes a decision about the number of effects accordingly. The method was shown to behave especially well with weak-moderate alternative hypothesis, high number of tests and low sample size. Since the SGoF method only controls for FWER in the weak sense i.e. under the complete null hypothesis, and since the FDR of SGoF is not keeping any a priori level, it seems





ARTIGOS

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EDICIONES COMPLUTENSE

# Camiños de ida e volta: a emigración herdada

Ana Acuña Trabazo[1]; María Luísa Márquez Rodríguez[2]; María Xosé Dourado Campos[3]

Recibido: 31 de marzo de 2016 / Aceptado: 31 de octubre de 2016

**Resumo.** "Camiños de ida e volta", nacido no IES Luís Seoane de Pontevedra servindo como ponte con Cuba (A Habana, Santa Clara) e Arxentina (Bos Aires, Río Ceballos, Capilla del Monte, Córdoba), xurdiu co obxectivo de dar resposta ao desarraigo dun grupo de estudantes arrincados polos seus país do seu país e das súas escolas e traídos a Galiza, unha terra para eles coñecida a través dos recordos dos seus avós e pola súa participación en eventos dos centros galegos aos que acudían en comunidade, ainda que axiña se converteu en algo máis: na recuperación dunha parte importante da memoria de Galiza a través das historias familiares. Os relatos recollidos coas voces dos protagonistas da diáspora ou dos seus descendentes, a posibilidade que nos regalaron de poder dixitalizar fotografías, documentos gardados durante décadas (pasaportes, autorizacións de traballo, partidas de nacimento, epistolarios cos que acó ficaban) transformáronse nun tesouro conservado no arquivo do noso instituto. Co traballo coñecemos elementos patrimoniais (gastronomía, música, artesanías, lendas, ditos...) coidados con amor e transmitidos, que conforman parte da identidade cultural dos países de acollida. A isto sumouse a experiencia de coñecemento arredor de Luís Seoane en Bos Aires, fundamentalmente o da súa produción muralística.

**Palabras chave**: Retorno; identidade; memoria familiar; emigración; Luís Seoane; Galiza.

## [es] Caminos de ida y vuelta: la emigración heredada

**Resumen.** "Caminos de ida y vuelta", nacido en el IES Luís Seoane de Pontevedra sirviendo como puente con Cuba (La Habana, Santa Clara) y Argentina (Buenos Aires, Río Ceballos, Capilla del Monte, Córdoba), surgió con el objetivo de dar respuesta al desarraigo de un grupo de estudiantes arrancados por sus padres de su país y de sus escuelas y traídos a Galicia, un territorio conocido por ellos a través de los recuerdos de sus abuelos y a través de los centros gallegos a los que acudían sus familias, aunque pronto se convirtió en algo más: en la recuperación de una parte importante de la historia de Galicia mediante las historias familiares. Los relatos recogidos con las voces de los protagonistas de la diáspora o de sus descendientes, la posibilidad que nos regalaron de poder digitalizar fotografías, documentos custodiados durante décadas (pasaportes, autorizaciones de trabajo, partidas de nacimiento, epistolarios con sus familiares) se transformaron en un tesoro conservado en el archivo de nuestro instituto. Con sus aportaciones conocemos elementos patrimoniales (gastronomía, música, artesanías, leyendas, dichos...) mimados y transmitidos, que hoy forman parte de la identidad cultural de los países de acogida. A esto hay que sumar la experiencia de conocer la figura de Luís Seoane en Buenos Aires, fundamentalmente su producción muralística.

**Palabras clave**: Retorno; identidad; memoria familiar; emigración; Luís Seoane; Galicia.

## [en] Roads Leading Out and In: the Legacy of Inmigration

**Abstract.** "Caminos de ida e volta" has its origins in Luis Seoane high school and it bridges the gap between Cuba (La Habana, Santa Clara) and Argentina (Buenos Aires, Río Ceballos, Capilla del Monte, Córdoba). It was born with the objective of giving answer to the alienation of a group of students who were once forced by their parents to leave their countries and school and were brought to Galicia. Galicia is for them a familiar land, for their grandparents' memories and their involvement in the different events held by the Galician centres in which their families took part. This soon led to the recovery of a very important part of Galician history through family stories. Tales collected with the diaspora

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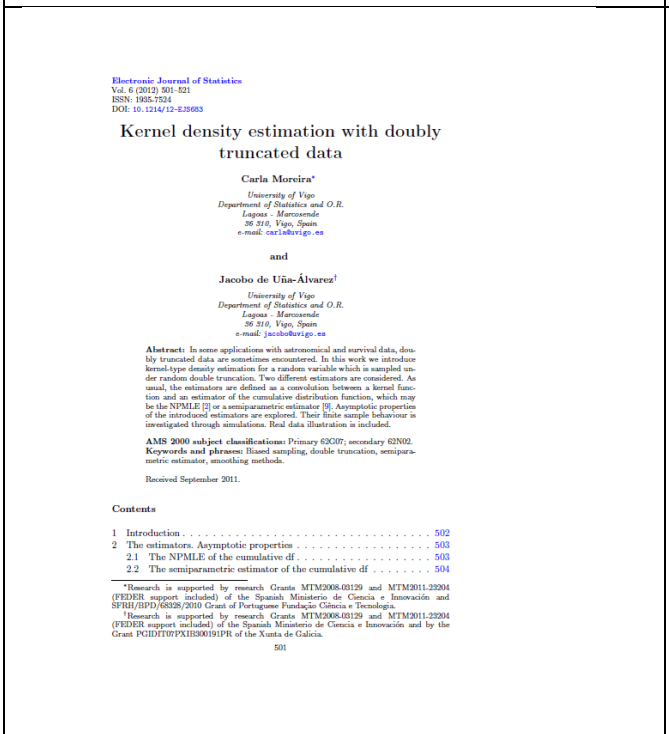

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# Kernel density estimation with doubly truncated data

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**Abstract:** In some applications with astronomical and survival data, doubly truncated data are sometimes encountered. In this work we introduce kernel-type density estimation for a random variable which is sampled under random double truncation. Two different estimators are considered. As usual, the estimators are defined as a convolution between a kernel function and an estimator of the cumulative distribution function, which may be the NPMLE [2] or a semiparametric estimator [9]. Asymptotic properties of the introduced estimators are explored. Their finite sample behaviour is investigated through simulations. Real data illustration is included.

**AMS 2000 subject classifications:** Primary 62G07; secondary 62N02.
**Keywords and phrases:** Biased sampling, double truncation, semiparametric estimator, smoothing methods.

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**Contents**



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*Research Article*

# Forecasting $SO_2$ Pollution Incidents by means of Elman Artificial Neural Networks and ARIMA Models

**Antonio Bernardo Sánchez,[1] Celestino Ordóñez,[2] Fernando Sánchez Lasheras,[1] Francisco Javier de Cos Juez,[2] and Javier Roca-Pardiñas[3]**

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An $SO_2$ emission episode at coal-fired power station occurs when the series of bihourly average of $SO_2$ concentration, taken at 5-minute intervals, is greater than a specific value. Advance prediction of these episodes of pollution is very important for companies generating electricity by burning coal since it allows them to take appropriate preventive measures. In order to forecast $SO_2$ pollution episodes, three different methods were tested: Elman neural networks, autoregressive integrated moving average (ARIMA) models, and a hybrid method combining both. The three methods were applied to a time series of $SO_2$ concentrations registered in a control station in the vicinity of a coal-fired power station. The results obtained showed a better performance of the hybrid method over the Elman networks and the ARIMA models. The best prediction was obtained 115 minutes in advance by the hybrid model.

## 1. Introduction

Coal-fired power stations are a major source of atmospheric pollutants, $SO_2$ being one of the most significant. Mixed with rain, with $SO_2$ is transformed into sulfuric acid producing acid rain. The wind helps to transport this element thousands of kilometers until it settles on the ground causing various negative effects. Sulfuric acid causes respiratory irritation, sometimes leading to damage to lung tissue.

European legislation on air pollution from coal-fired power stations establishes limits for the emissions of $SO_2$. Specifically, it imposes a limit on the average of 24 consecutive concentrations of $SO_2$ taken at 5-minute intervals. An emission episode is said to occur when the series of biannual averages is greater than a threshold set by current regulations. The interest is in predicting emission episodes with at least one hour in advance.

Forecasting $SO_2$ levels can be addressed through mathematical models such as autoregressive-moving-average (ARMA) or artificial neural networks (ANNs) models. An ARMA model was used by Hassanzadeh et al. in 2009 [1] to forecast $SO_2$ levels for five stations. According to their results, an ARMA (2,2) model provides reliable predictions. Kandya and Mohan [2] study the forecasting of $SO_2$ (and other pollutants) using five statistical techniques. Although each technique has its own advantages and limitations, they found that the one-day prediction autoregressive integrated moving average (ARIMA) [3] technique scores well over the other techniques. Goyal et al. [4] pointed out that linear models such as multilinear regression MLR and ARIMA fail to predict extreme concentrations of pollutants.

Neural networks have also been used to predict concentrations of $SO_2$ and other pollutants emitted by a power plant. Mok and Tam [5] used three-layered feed-forward artificial neural networks to predict the daily $SO_2$ concentration 5 days in advance. Nunnari et al. [6] compared multilayer perceptron (MLP) models with a neurofuzzy approach and an autoregressive-moving-average model with exogenous inputs (ARMAX) model. The results confirmed the superiority of the MLP model over the other. Pérez et al. [7] compared the forecasting produced by three different methods (MLP, multiple linear regression (MLR), and persistence methods).

## Artigos publicados en revistas híbridas

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PERSPECTIVE

### Fisheries regulatory regimes and resilience to climate change

Elena Ojea, Isaac Pearlman, Steven D. Gaines, Sarah E. Lester

Received: 8 October 2015 / Revised: 25 February 2016 / Accepted: 27 October 2016 / Published online: 16 November 2016

**Abstract** Climate change is already producing ecological, social, and economic impacts on fisheries, and these effects are expected to increase in frequency and magnitude in the future. Fisheries governance and regulations can alter socio-ecological resilience to climate change impacts via harvest control rules and incentives driving fisher behavior, yet there are no syntheses or conceptual frameworks for examining how institutions and their regulatory approaches can alter fisheries resilience to climate change. We identify nine key climate resilience criteria for fisheries socio-ecological systems (SES), defining resilience as the ability of the coupled system of interacting social and ecological components (i.e., the SES) to absorb change while avoiding transformation into a different undesirable state. We then evaluate the capacity of four fisheries regulatory systems that vary in their degree of property rights, including open access, limited entry, and two types of rights-based management, to increase or inhibit resilience. Our exploratory assessment of evidence in the literature suggests that these regulatory regimes vary widely in their ability to promote resilient fisheries, with rights-based approaches appearing to offer more resilience benefits in many cases, but detailed characteristics of the regulatory instruments are fundamental.

**Keywords** Climate change adaptation · Fisheries systems · Resilience · Socio-ecological systems

**INTRODUCTION**

Marine systems have been and will continue to be impacted by climate change across all habitats, latitudes, and trophic levels (Hoegh-Guldberg and Bruno 2010; Richardson et al. 2012; Poloczanska et al. 2013; Rhein et al. 2013). These impacts trickle up to the fisheries that humans depend upon via alterations in primary productivity (Poloczanska et al. 2013), food webs (Edwards and Richardson 2004), and community structure (Barange and Perry 2009). These ecological shifts will produce both positive and negative impacts (Cheung et al. 2012), but are expected to affect fishers and fishing communities via altered fishing revenues, increased costs per unit effort, higher insurance costs, and/or changes in international fishing agreements, among others (Adger et al. 2009; Badjeck et al. 2010; Sumaila et al. 2011). Thus, there is a need for fisheries management that promotes resilient social and ecological systems in order to ensure long-term sustainability (Adger et al. 2009; Grafton 2009).

While ecological resilience is traditionally defined as the *resistance* of ecosystems or species to disturbance, and the speed of *recovery* following disturbance (Holling 1973); in social systems resilience is related to the disturbance, reorganization, and renewal of communities and institutions (Grafton 2009). Here we define socio-ecological resilience as the ability of a SES to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organization, and the capacity to adapt to stress and change (IPCC 2007, Davidson et al. 2013). Social–ecological resilience refers to people and nature as inter-dependent systems (Folke et al. 2010), where changes in ecological resilience affect social resilience and vice versa.

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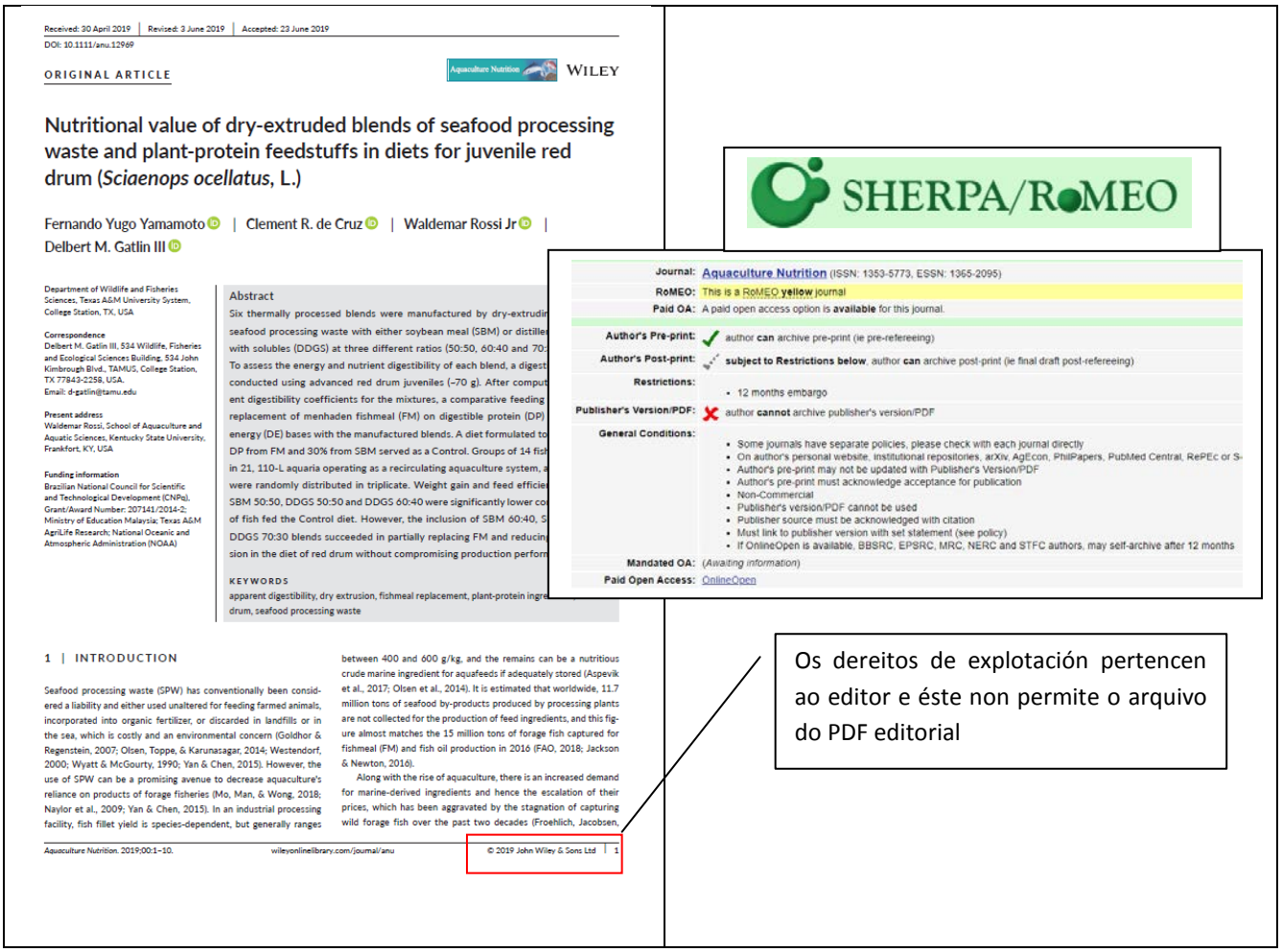

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ORIGINAL ARTICLE

Aquaculture Nutrition WILEY

Nutritional value of dry-extruded blends of seafood processing waste and plant-protein feedstuffs in diets for juvenile red drum (*Sciaenops ocellatus*, L.)

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Abstract

Six thermally processed blends were manufactured by dry-extrudin seafood processing waste with either soybean meal (SBM) or distille with solubles (DDGS) at three different ratios (50:50, 60:40 and 70: To assess the energy and nutrient digestibility of each blend, a digest conducted using advanced red drum juveniles (~70 g). After comput ent digestibility coefficients for the mixtures, a comparative feeding replacement of menhaden fishmeal (FM) on digestible protein (DP) energy (DE) bases with the manufactured blends. A diet formulated to DP from FM and 30% from SBM served as a Control. Groups of 14 fish in 21, 110-L aquaria operating as a recirculating aquaculture system, a were randomly distributed in triplicate. Weight gain and feed efficie SBM 50:50, DDGS 50:50 and DDGS 60:40 were significantly lower co of fish fed the Control diet. However, the inclusion of SBM 60:40, S DDGS 70:30 blends succeeded in partially replacing FM and reducin sion in the diet of red drum without compromising production perfor

KEYWORDS
apparent digestibility, dry extrusion, fishmeal replacement, plant-protein ingre drum, seafood processing waste

1 | INTRODUCTION

Seafood processing waste (SPW) has conventionally been considered a liability and either used unaltered for feeding farmed animals, incorporated into organic fertilizer, or discarded in landfills or in the sea, which is costly and an environmental concern (Goldhor & Regenstein, 2007; Olsen, Toppe, & Karunasagar, 2014; Westendorf, 2000; Wyatt & McGourty, 1990; Yan & Chen, 2015). However, the use of SPW can be a promising avenue to decrease aquaculture's reliance on products of forage fisheries (Mo, Man, & Wong, 2018; Naylor et al., 2009; Yan & Chen, 2015). In an industrial processing facility, fish fillet yield is species-dependent, but generally ranges between 400 and 600 g/kg, and the remains can be a nutritious crude marine ingredient for aquafeeds if adequately stored (Aspevik et al., 2017; Olsen et al., 2014). It is estimated that worldwide, 11.7 million tons of seafood by-products produced by processing plants are not collected for the production of feed ingredients, and this figure almost matches the 15 million tons of forage fish captured for fishmeal (FM) and fish oil production in 2016 (FAO, 2018; Jackson & Newton, 2016).

Along with the rise of aquaculture, there is an increased demand for marine-derived ingredients and hence the escalation of their prices, which has been aggravated by the stagnation of capturing wild forage fish over the past two decades (Froehlich, Jacobsen,

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Carbon accounting systems

# When carbon accounting systems make us forget nature: from commodification to reification

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**Findings** – The paper presents and discusses three mechanisms (the objectivation of nature, economic reasoning and individuals' environmental consciousness) that form the basis for the rationale and modus operandi of carbon accounting systems. By comparing these mechanisms with the concept of reification, it highlights three criticisms that could be put to advocates of these systems.

**Practical implications** – This analysis shows that discussions of carbon accounting systems should focus more on their philosophical principles rather than merely examining the technical problems posed by their implementation.

**Social implications** – This research provides some answers to explain the inefficiency of policies implemented within the framework of global climate governance.

**Originality/value** – This study helps to put carbon accounting research into perspective. It goes further than existing work on the commodification of nature by describing the subjective dimension of individuals who are led to disconnect their arguments and practices from their primary and emotional relationship with nature.

**Keywords** Carbon footprint, Carbon accounting, Climate governance, Carbon market, GHG inventory, Reification, Commodification of nature

**Paper type** Conceptual paper

## 1. Introduction

The First World Climate Conference, organized in Geneva (Switzerland) in 1979 under the auspices of the United Nations, highlighted the problem of global warming as an international priority and, today, few scientists, politicians and economic leaders question the reality of the impact of human activities on the climate, and the need to act to keep the rise in the Earth's temperature within acceptable limits for future generations. The work of the Intergovernmental Panel on Climate Change (IPCC), which was created in 1988, has provided the basis for numerous measures that have been implemented globally, nationally and locally with the aim of reducing the use of fossil fuels, promoting renewable or low

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# Toxicity tests of cryoprotecting agents for *Mytilus galloprovincialis* (Lamark, 1819) early developmental stages

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ABSTRACT

Global aquaculture production of blue mussel has increased over last years. This work reaffirms the great potential of cryopreservation technique on mussel industry and overcome economic barriers a cause of a traditional and rudimentary management and continue growing. The aim of this work is to set some preliminary basis attending to toxicity of cryoprotecting agents (CPAs) on different development stages of *Mytilus galloprovincialis* as a start point to develop a stable cryopreservation protocol. Toxicity tests were carried out by using common CPAs (dimethyl-sulfoxide ($Me_2SO$), glycerol, (GLY), propylene glycol (PG) and ethylene glycol (EG)) in a range from 0,5 to 3 M on fertilized egg, trochophore larva, and D-larva of *Mytilus galloprovincialis*. Results evidenced more resistance of older development stages to toxicity. Of all CPAs tested, toxicity testing highlights PG or EG as suitable CPAs for cryopreservation of early development stages; whereas D-larva was unaffected by any of the CPAs tested. Preliminary cryopreservation trials were developed to obtain information into cell cryoprotection. Further research should be focused on membrane permeability and other parameters, such as the balance between toxicity and cryoprotective effect of CPAs.

## 1. Introduction

Mussels are among the most farmed species in the aquaculture industry. In fact, 116,262 tons were produced worldwide in 2014 [54]. Spain is the second higher producer of mussels (preceded by China); more than 100,000 tons are consumed annually. Despite the demand, the Spanish production has not increased during last years a cause of biological, technological and socioeconomic factors.

Aquaculture industry, biological, biotechnological sciences and agriculture requires preservation of biological material in a stable state to get it at the time of need. In these lines, cryopreservation is accepted as preferred technique for achieving long-term storage [36].

Mollusc aquaculture has been intensively developed over the last 60 years [20]; although an increasing of the research effort is necessary to improve aquaculture techniques to maintain the competitive development of the industry and a long-term sustainable production. In recent years, many studies about cryopreservation applied to marine organisms have been published, most of them concerning fish species. However, there has been research focused on the improvement of mollusc cryopreservation procedures, mainly species included in the *Crassostrea* genus, due their economic importance [5,32].

Aquaculture production will benefit from the development of successful cryopreservation protocols for marine organisms [2–4,21,23,33,35]. It ensures stable and sustainable shellfish resources and decreases mortality due associated risks such as; diseases caused by specific parasites or virus such as; *Crassostrea gigas* with Ostreeid herpes virus 1 (OsHV-1), *Mytilus* sp. with *Blastia doellojuradoi* and *Nepinotsthera novaezealandiae* or *M. interinalis* with *Marteilia* sp. [31] or natural/anthropologic disruptive events. According to FAO in 2010, the predation and diseases caused by parasites, such as *Mytilicola intestinalis* or *Marteilia* sp. do not currently affect the global mussel production. However, as a precaution there is an exhaustive monitoring program to evaluate mussel mortality and state of water quality to limit the mussel mortality due diseases or water pollution [54].

Moreover, the development of cryopreservation techniques could be used to provide a reference back-up copy of a family for selective breeding, enabling parental crosses on demand and enhancing breeding design flexibility. In hatcheries, progenies without seasonal limitations could be produced and genetic obstacles could be overcame. The

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