Invasive Alien Species: Terminology and Definitions

An Introduction to Diversity and Patterns of Marine Alien Species in the Macaronesia

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arditi

Background and motivation

What is biodiversity?

- Refers to the **numbers**, **variety** and **variability** of living organisms and ecosystem
- Includes all terrestrial, marine and other aquatic organisms

CONSERVATION

Background and motivation

Major biodiversity threats:

Habitat destruction

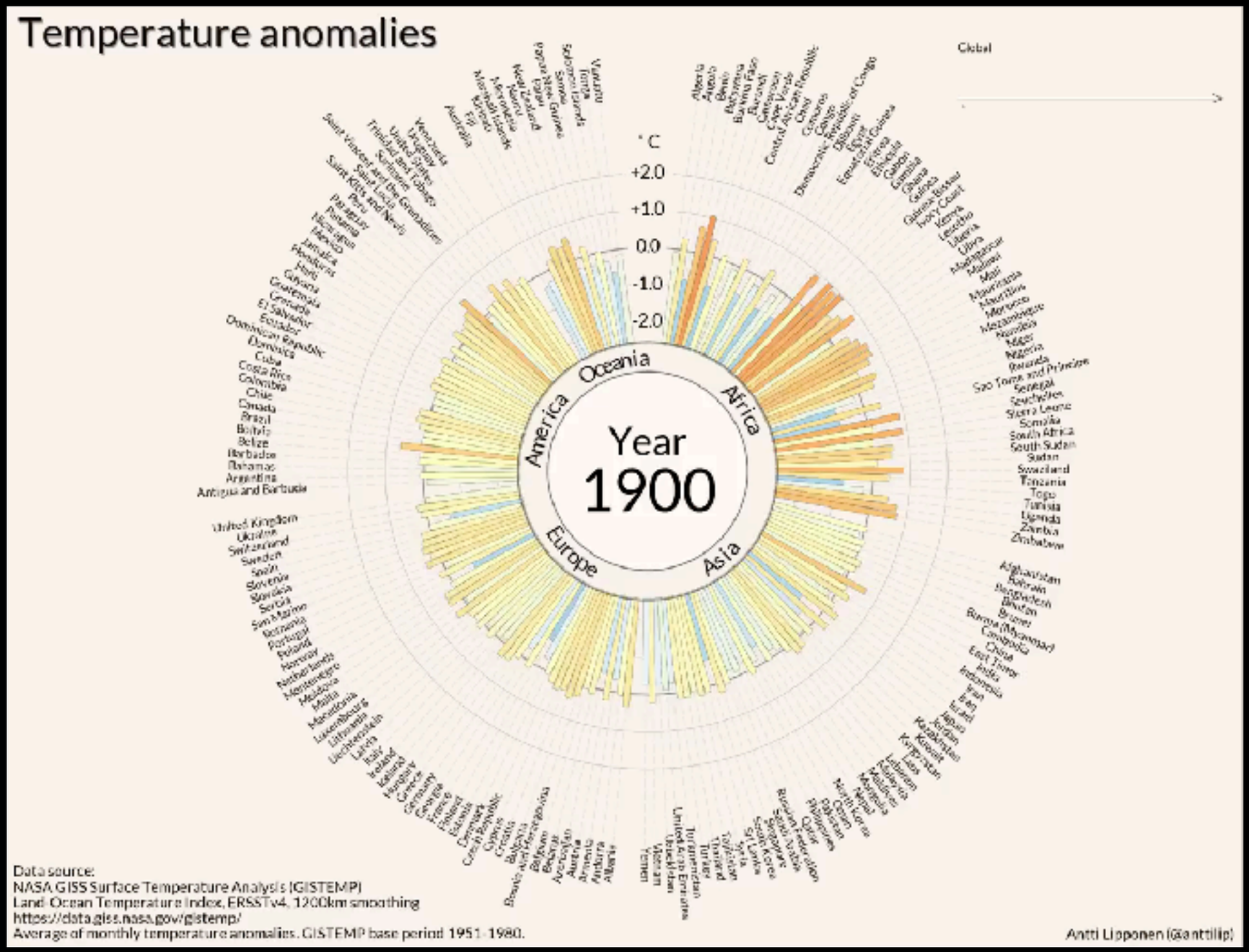
Marine litter

Invasive species

Overexploitation

Background and motivation

Major biodiversity threats:



Dr. Antti Lipponen @anttilip

Climate change is happening!

The Invasion Process

Transport

Introduction

Failure

Establishment

Remain local

Spread

Low

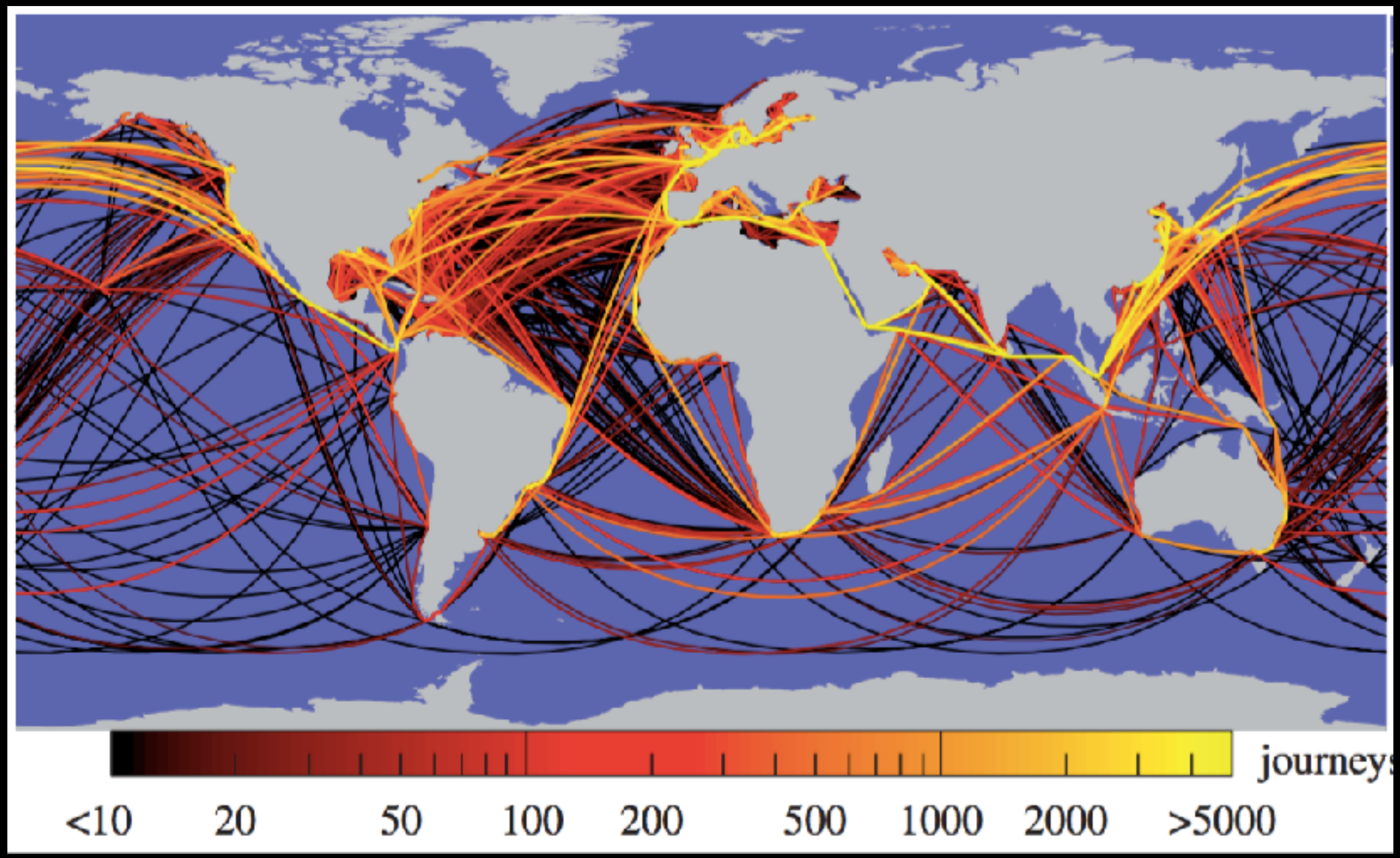
IMPACT

High

(adapted from Sakai *et al.* 2001; Moyle & Marchetti 2006)

Vectors and pathways of introduction

1. Shipping



The complex network of global cargo ship movements

Kaluza et al, 2010

Vectors and pathways of introduction

1.1. Hull fouling

1.2. Ballast water

http://invasions.si.edu/nbic/managementpract.html

Vectors and pathways of introduction

2. Aquaculture

Vectors and pathways of introduction

3. Public Aquaria

http://reeftools.com/news/70000-square-feet-public-aquarium-to-be-built-in-cleveland/

Vectors and pathways of introduction

4. Drilling platforms

http://oil-platforms.oilrigdrillings.com/

Vectors and pathways of introduction

5. Canals

http://en.wikipedia.org/wiki/Manchester_Ship_Canal

Vectors and pathways of introduction

6. Live bait

Miller et al, 2010, NOAA Sea grant

Vectors and pathways of introduction

6. Live bait

Ascophyllum nodosum
Fucus spp.

Miller et al, 2010, NOAA Sea grant

Vectors and pathways of introduction

7. Research

Vectors and pathways of introduction

8. an unthinkable vector (2011, Japan)

http://au.ibtimes.com/articles_slideshows/121979/20110312/scenes-of-destruction-in-aftermath-of-japan-earthquake-photos_6.htm#article_header

Vectors and pathways of introduction

- Earthquake 9.0 magnitude
- Epicentre at 72 km of the coast
- 6 minutes of destruction
- Tsunami, waves >30m
- 15.883 casualties….
- 2600 missing….
- 6.000 injured…
- Billions of dollars in impact

NOAA

Vectors and pathways of introduction

Question: What is the possible relationship between the Japanese tsunami and NIS proliferation?

- April 2012, in Alaska
- May 2012, in BC
- > 5000 km

Vectors and pathways of introduction

- June 2012, in Oregon
- 20 m long
- 6 m high

http://www.brucesussman.com/earthquakes-volcanoes/by-the-numbers-japan-tsunami-debris-hits-oregon-coast/

NOAA

Terminology and Definitions

What is an Alien species?

Exotic

Fish

introduced

Invasive alien

non-native

alien

Botanists

Non-Indigenous Species (NIS)

Invasive

Terminology and Definitions

- Interest and Subscription to the science of biological invasions has increased vastly

Hits on Google Scholar:

	Jan 2011	April 2014	Oct 2018
Non-indigenous	61,000	154,000	361,000
Biological invasions	27,000	56,300	111,000
Invasive species	59,500	190,000	**1,320,000**

Inevitably, this proliferation of literature leads to enduring and growing complications and challenges in the uniform understanding and interpretation of basic concepts

James T. Carlton, 2018

Terminology and Definitions

Between 1984 and 2018 (to date)**, *in English alone,***
<u>106 papers and book chapters</u>* have been published on the **language and terminology of biological invasions**, from the perspectives of,

- science
- environmental history
- cultural anthropology
- sociology
- economics
- management (prevention / control)

88% of these appeared in 2000-2018

(**47%** since 2005)

Since 2005*, **more than 100 books have been published on biological invasions

James T. Carlton, 2018

Terminology and Definitions

In case you lost track … invasive means:

Usher	1986	impact (pests)
CBD	1993	impact (biodiversity)
Pysek	1995	spread/abundance increasing
US Exec	1999	impact (multiple levels of harm)
Richardson	2000	spread (not impact!)
Colautti	2004	widespread and impact (“dominant”)
Ricciardi	2007	spread (not impact!)
Beck	2008	impact (harm)
Blackburn	2011	spread (it’s not impact!)
Mooney	2011	impact
Piraino	2014	impact, not spread
Guy-Haim	2018	very much includes impact

Terminology and Definitions

- ….THERE IS NO CONSENSUS IN INVASION TERMINOLOGY!
  (Probably it never will…..)

BUT…… LET'S TRY…….

Terminology and Definitions

- Non-indigenous species - species that was moved outside its usual geographical range via anthropogenic actions (this could be intentional or accidental), irrespective of its impact on native species and native ecosystems.
- Invasive species - an invasive species by definition must be a NIS, but one that has caused demonstrable impact, both in ecological and economic terms.
- Cryptogenic species - a species of unknown origin or a species that is neither undoubtedly native nor NIS.
- Biological Invasion - This is a very broad term that refers to the introduction of NIS into new ecosystems/area/regions via human actions but also considers natural range expansions.
- Range Expansions - consist of dispersal by natural mechanisms into a region where the species did not formerly exist
- Propagule Pressure - the introduction effort, i.e. the pool of individuals introduced in a new ecosystem/area/region and the number of times it is released.

Canning-Clode, 2015

Invasions in Macaronesia

Islands have been used for:

Journey stops

Lighthouses

prisons

Farming

Destroying natural ecosystems and introducing Non-Indigenous Species (NIS)

Veitch et al 2011

Invasions in Macaronesia

NIS Introductions in islands

- Terrestrial realm (well documented)
- Marine realm (rarely studied)

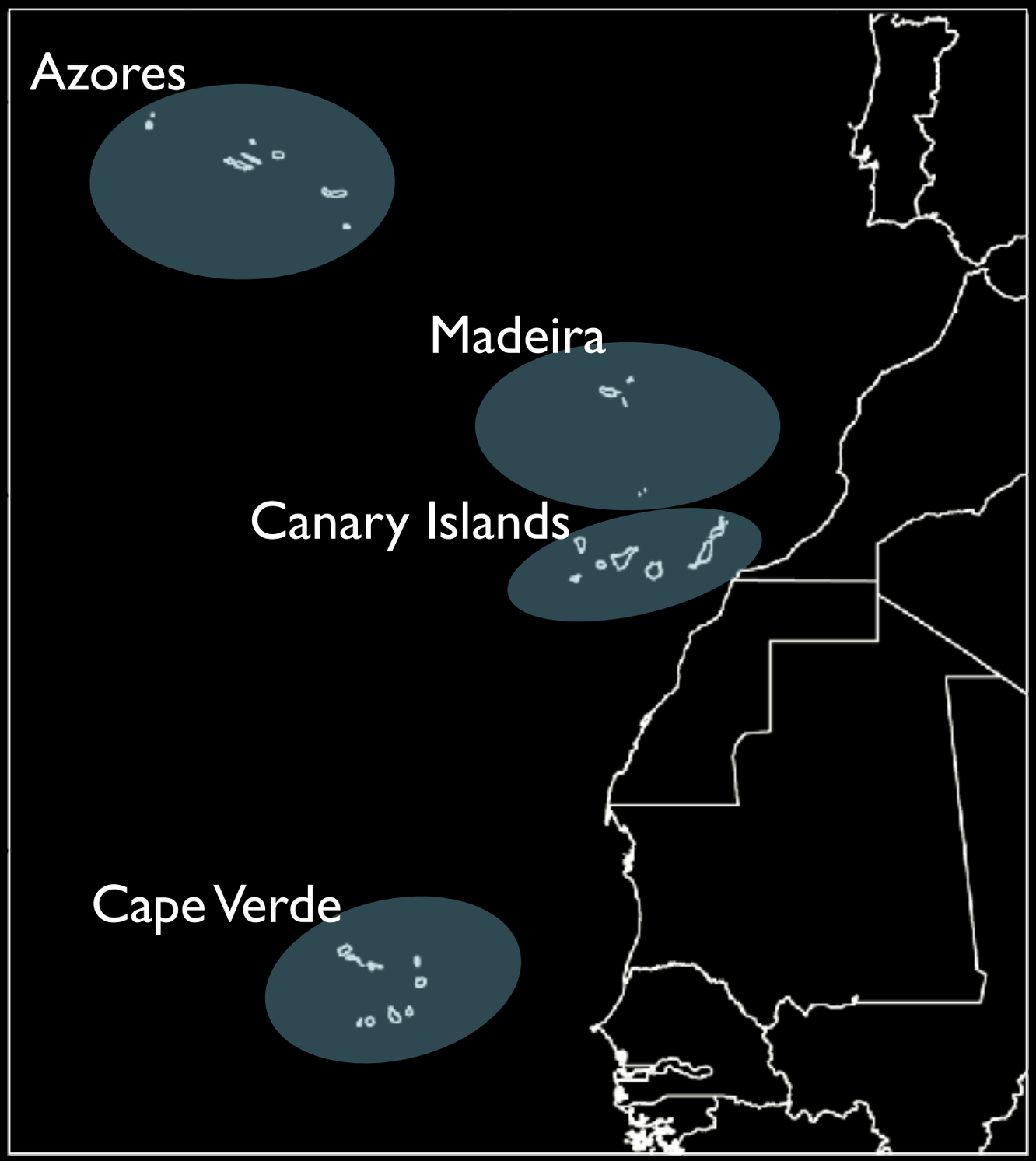
Exceptions:

- New Zealand (Pacific Ocean)
- Hawaiian Islands (Pacific Ocean)
- Guam (Pacific Ocean)
- Azores and Madeira (North Atlantic)

Lloret et al., 2005; Gaston et al., 2008; Veitch et al., 2011; Towns et al., 2012; Inglis et al., 2006; Carlton and Eldredge, 2009; Paulay et al., 2002; Cardigos et al 2006

Invasions in Macaronesia

MACARONESIA



- Volcanic origin, 27 islands.
- Portugal, Spain & Cape Verde
- Climate ranges from Mediterranean in Madeira and Azores and more arid in Canary islands and Cape Verde
- Laurel forest ('Laurissilva') - Subtropical forest, high humidity

Invasions in Macaronesia

Main goals:

- First comprehensive NIS list in Macaronesia *(what is there?)*
- Detect differences in NIS numbers and NIS composition across island systems
- Understand whether human activities are related with NIS numbers in each island

2 - Methods

Literature search:

Web of science
Scopus
Google scholar

Azores

Madeira

KEYWORDS:

Alien
invasive
Introduced
Non-invasive species
NIS
invasion
non-native
Exotic

Cape Verde

Canary Islands

2 - Methods

~200 documents
(1884 -2020)

- scientific papers
- books
- book chapters
- theses
- scientific reports

NIS → Each inhabited island (n=27)

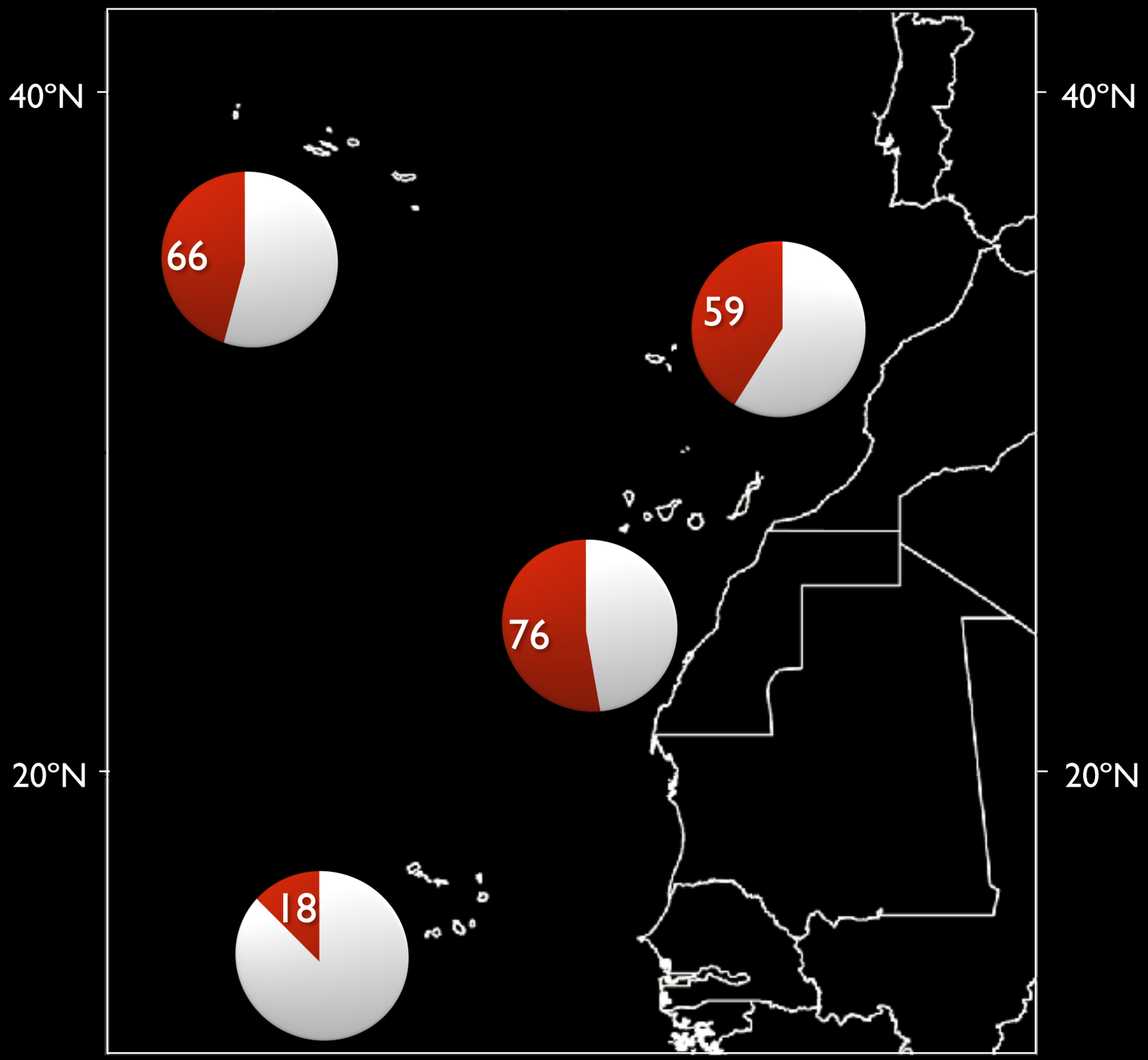
NIS numbers

- Island / island system
- Multivariate analysis
- Geographic and demographic variables
- Coastal development variables
- Shipping data

Negative binomial regression

Marine Invasions in Macaronesia

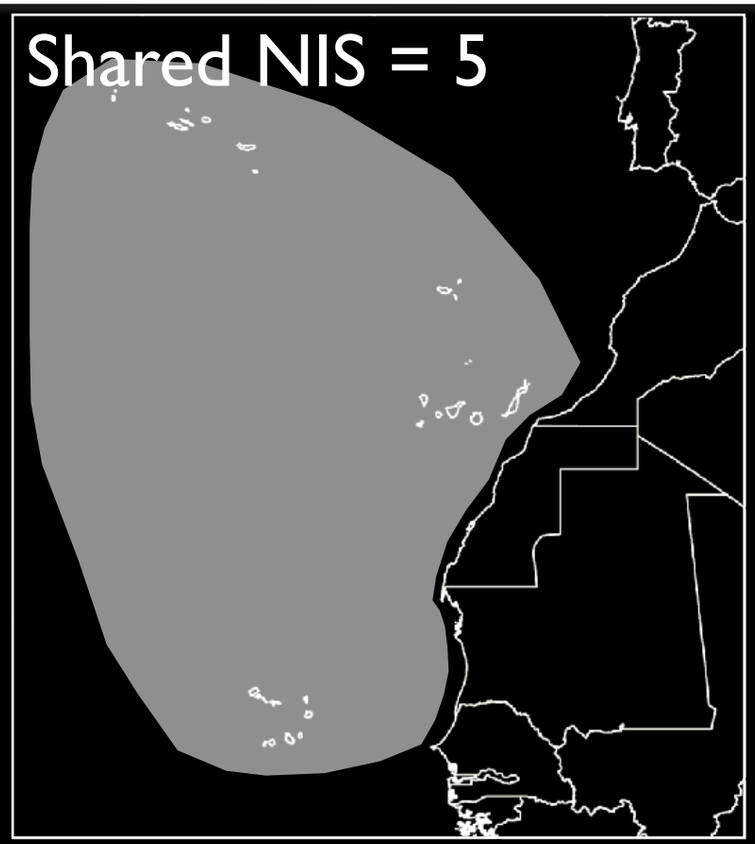
NIS richness

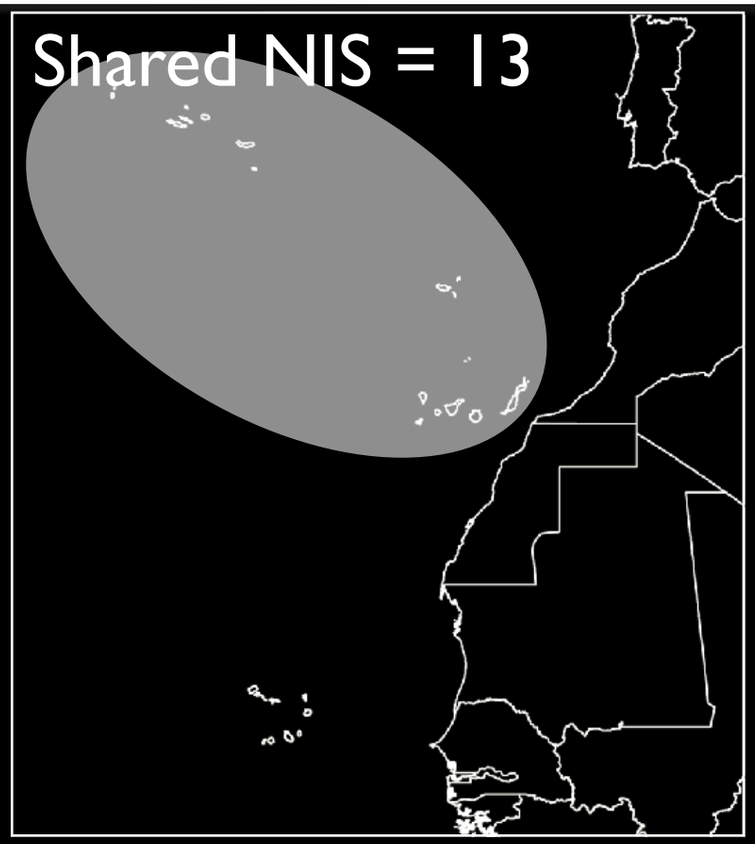


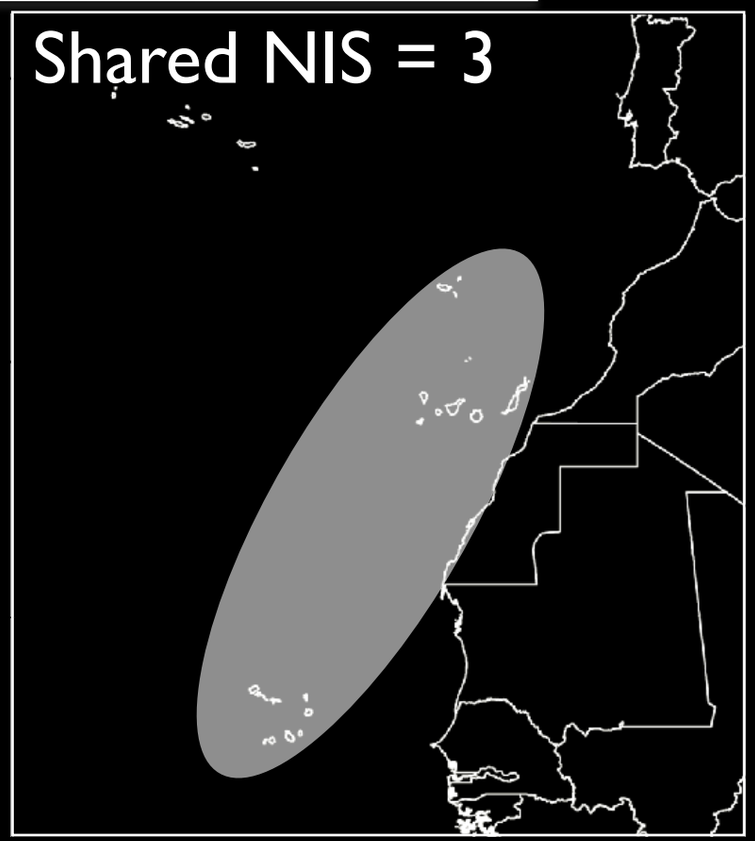
144 NIS

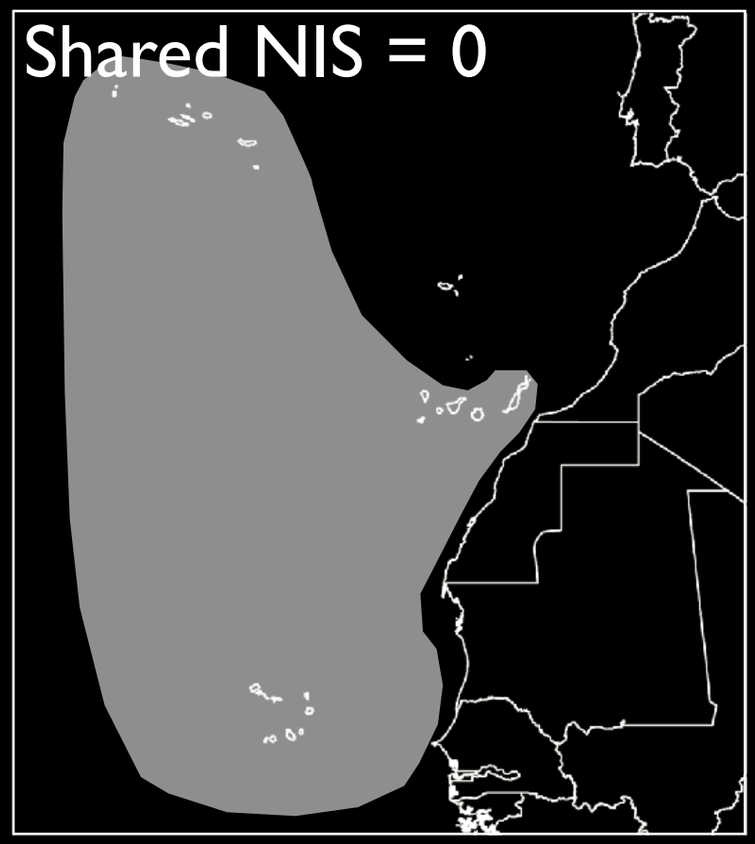
Castro et al., 2022

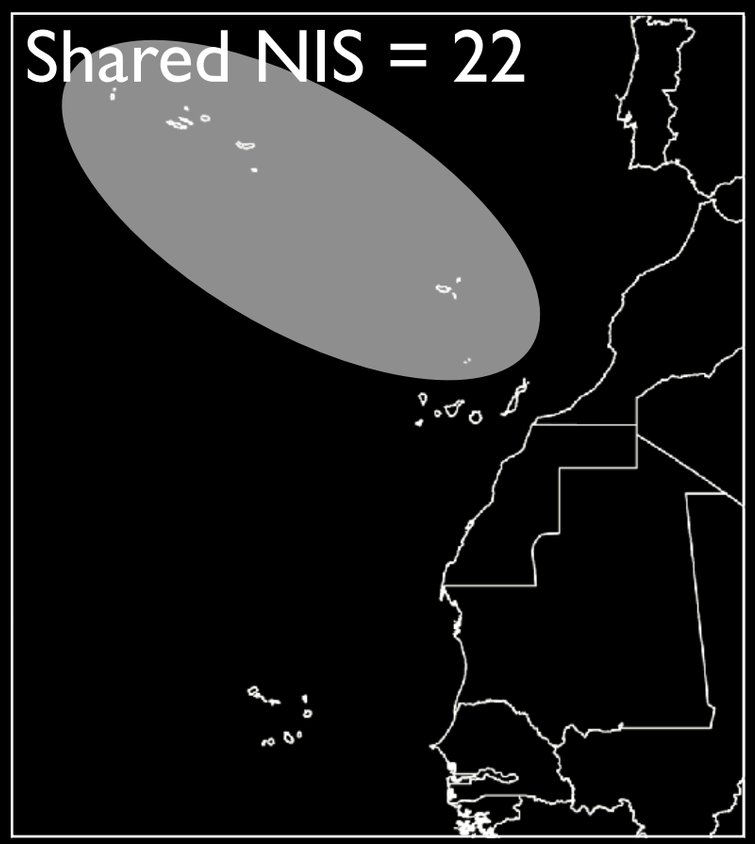
3 - Results

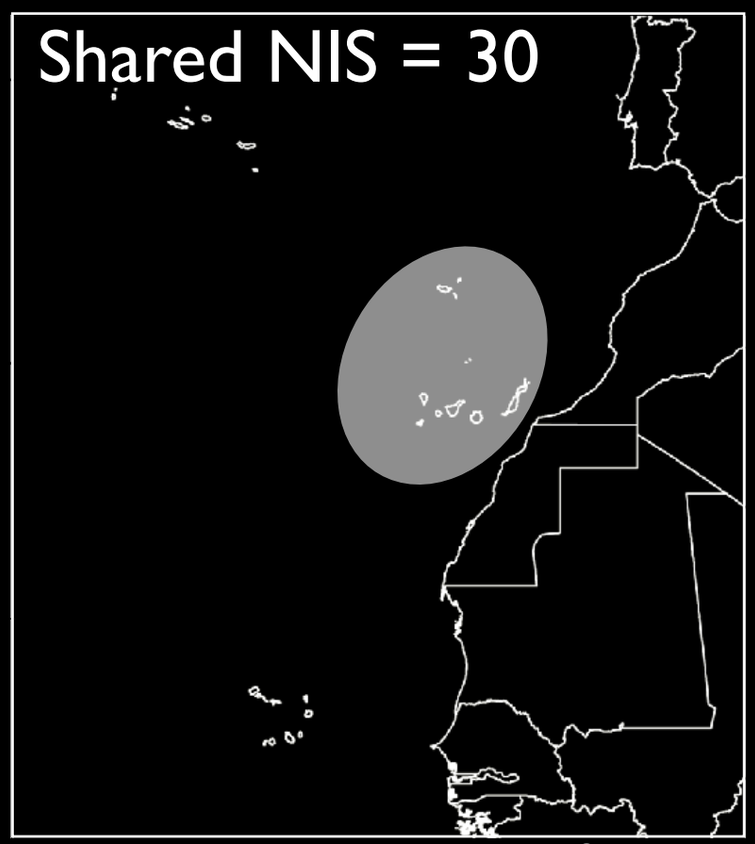








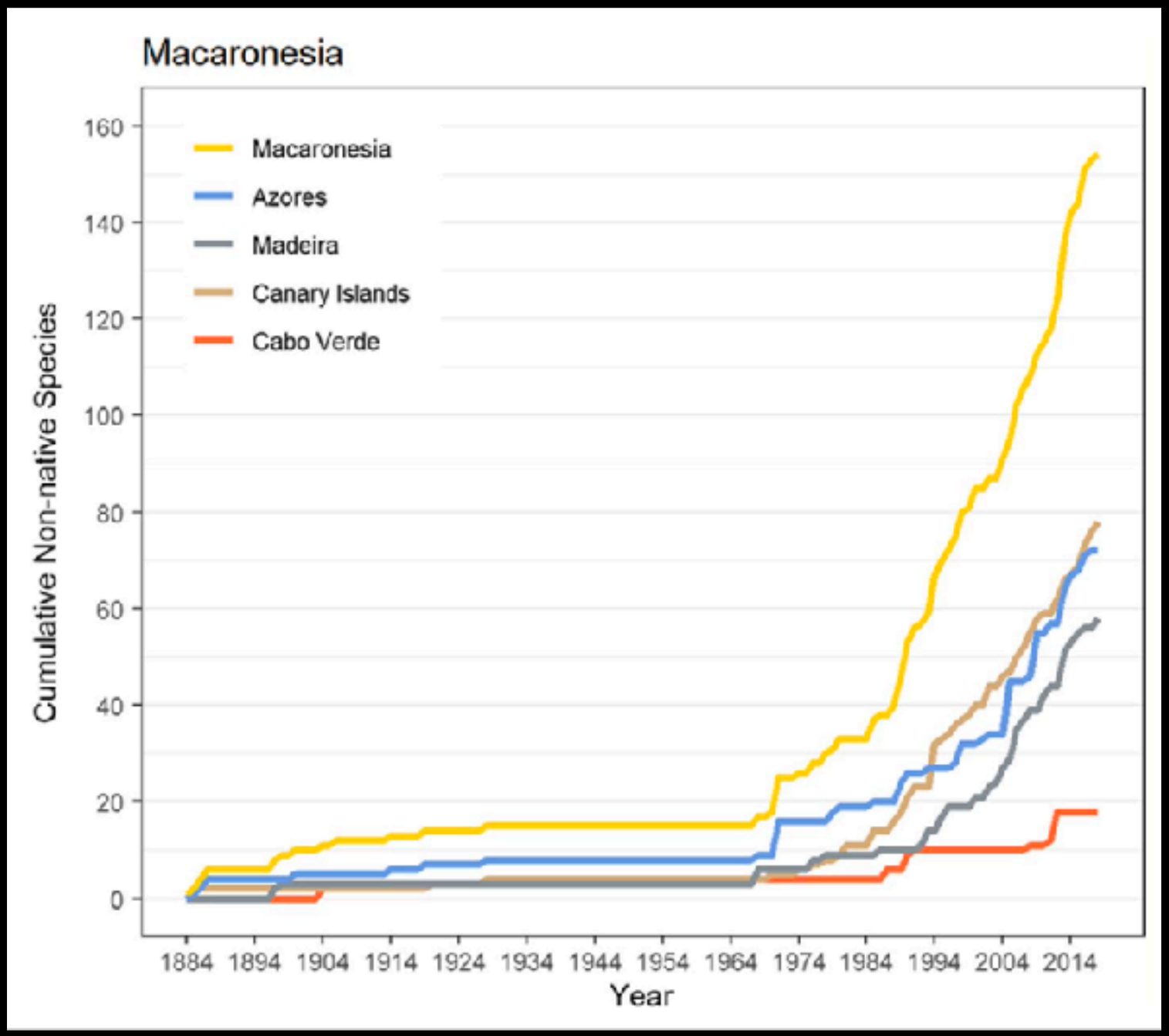




Castro et al., 2022

Marine Invasions in Macaronesia

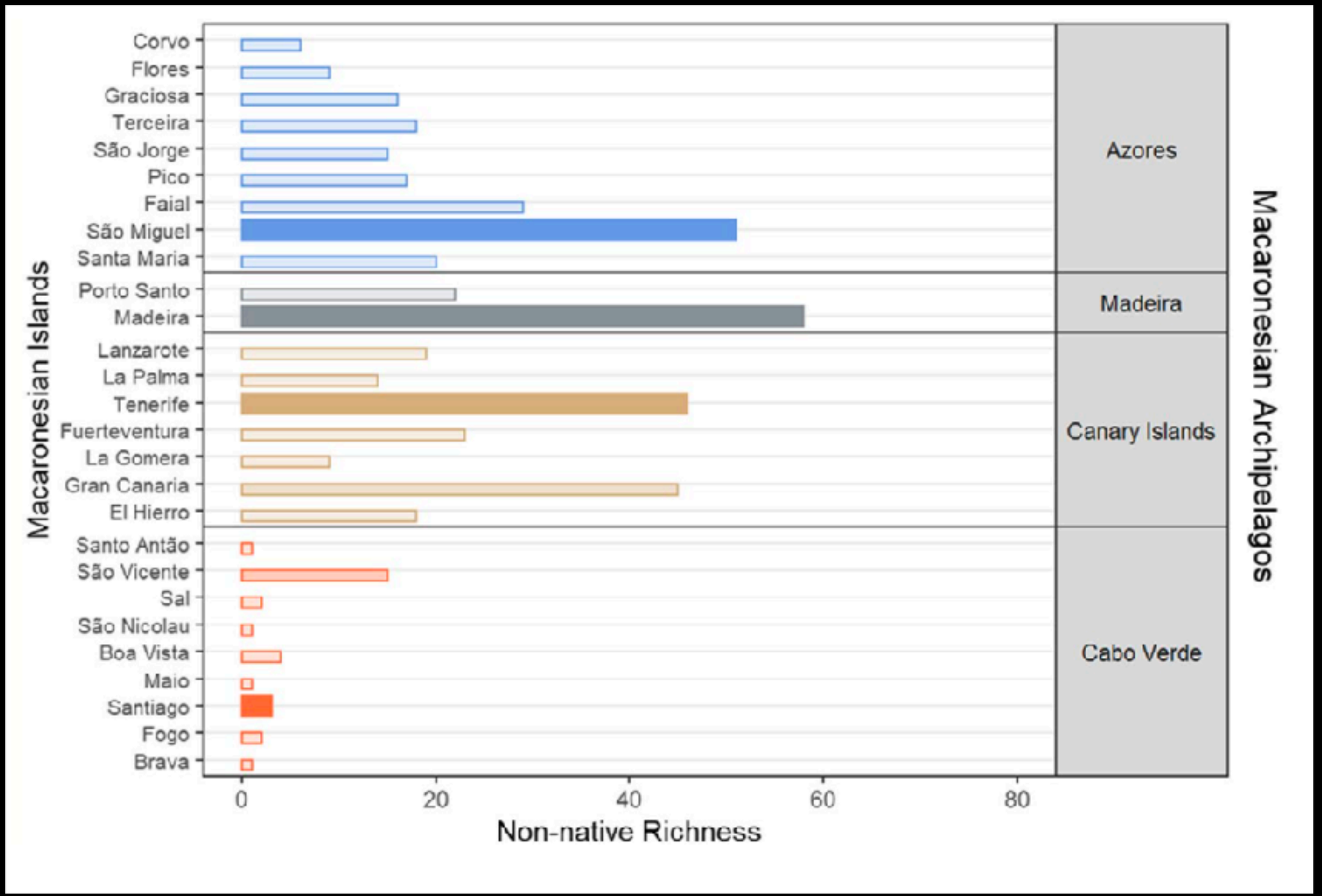
Accumulated NIS number over time



Castro et al., 2022

Marine Invasions in Macaronesia

NIS number in individual islands



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Marine Invasions in Macaronesia

Species composition

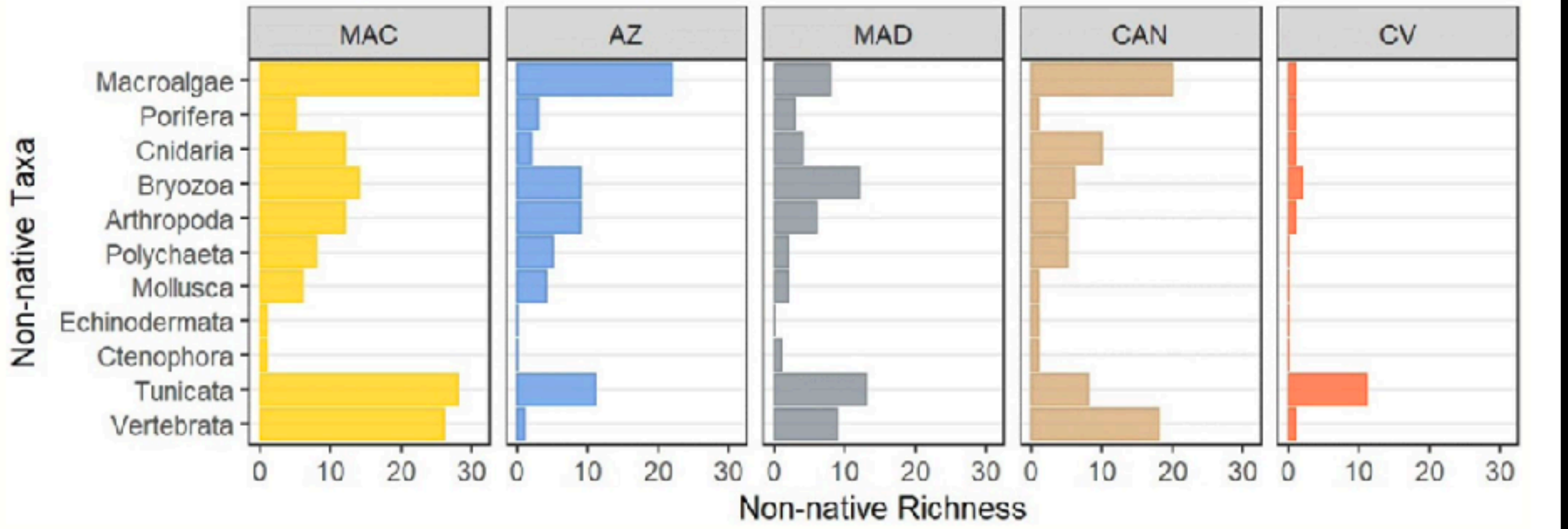


FIGURE 3 Most representative taxonomic groups for non-native species (NNS) in Macaronesia and each archipelago system (MAC—Macaronesia; AZ—Azores; MAD—Madeira; CAN—Canary Islands; CV—Cabo Verde)

Castro et al., 2022

Marine Invasions in Macaronesia

Negative Binomial GLM

TABLE 1 Estimated regression parameters, standard errors, *z*-values and *p*-values for the best Negative Binomial (NB) General Linear Model (GLM) presented regarding non-native species (NNS) richness as a function of anthropogenic, demographic and geographical variables

	Estimate	Std. error	z value	*p*-value
Intercept	5.458	0.7387	7.390	<.001
Mindist	−0.002	0.001	−3.849	<.001
Archipelago_codeCan	−1.562	0.382	−4.077	<.001
Archipelago_codeCV	−3.121	0.437	−7.142	<.001
Archipelago_codeMad	−1.112	0.365	−3.063	<.01
Total_marina_area	0.001	0.001	−3.589	<.001
Total_harbors_marinas	0.020	0.003	5.788	<.001

Note: The estimated value for Theta is 402 ± 3050.

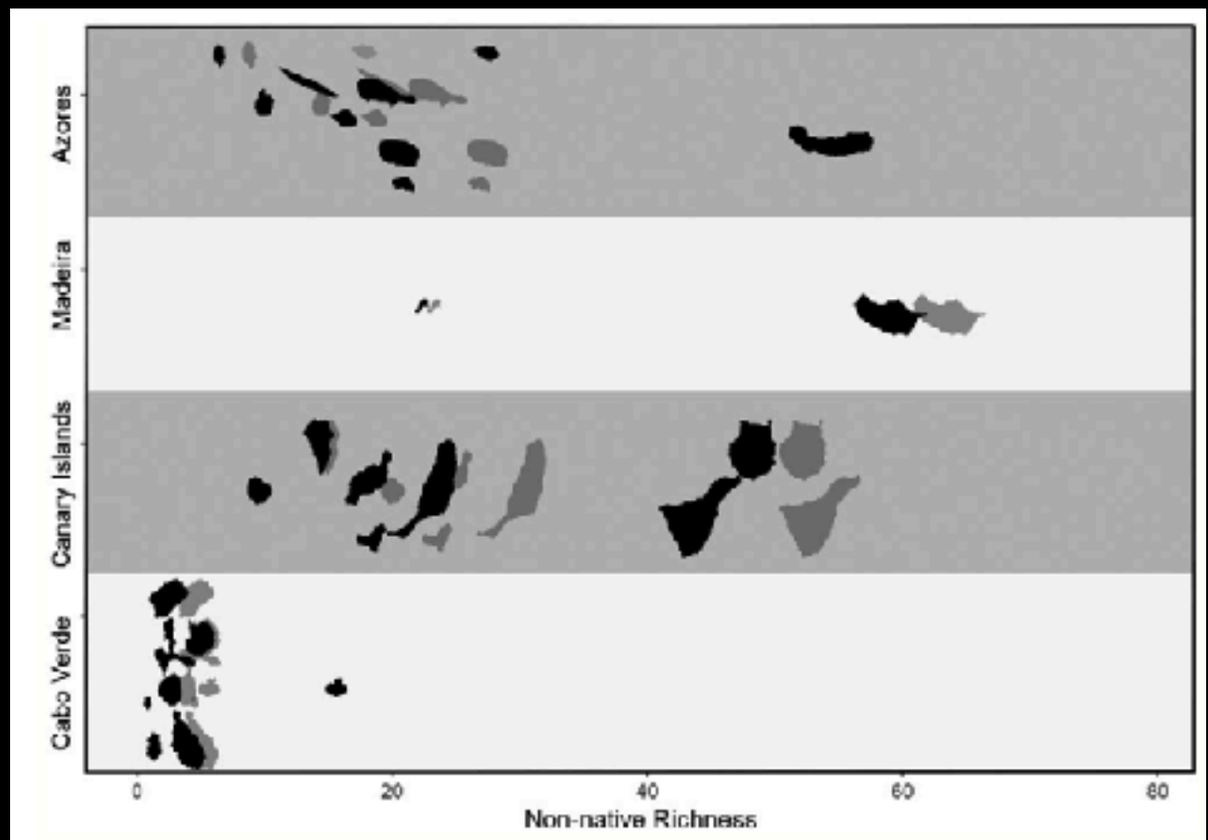
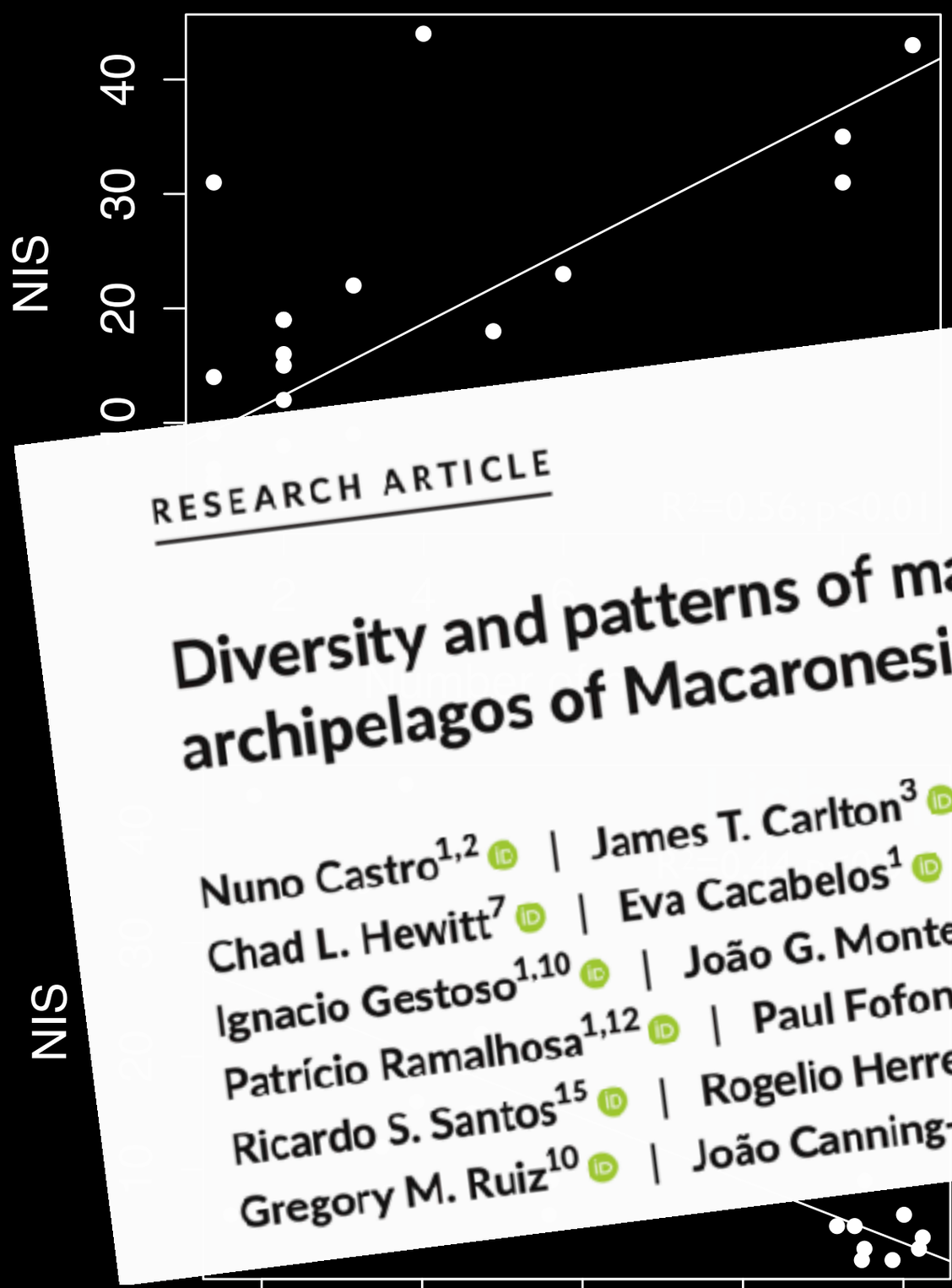


FIGURE 7 Non-native species (NNS) detected in the present study (black colour) and by the output results predicted by the selected Negative Binomial (NB) model (grey colour) for each island of the four Macaronesian archipelagos. When the models' prediction (grey colour) is not visible, the observed value (black colour) overlaps the predicted value. Predictions close to observed values might, therefore, not be visible

Castro et al., 2022

3 - Results (Coastal development)



RESEARCH ARTICLE

Diversity and Distributions WILEY

Diversity and patterns of marine non-native species in the archipelagos of Macaronesia

Nuno Castro[1,2] | James T. Carlton[3] | Ana C. Costa[4,5] | Carolina S. Marques[6] | Chad L. Hewitt[7] | Eva Cacabelos[1] | Evandro Lopes[8,9] | Francesca Gizzi[1] | Ignacio Gestoso[1,10] | João G. Monteiro[1] | José L. Costa[2,11] | Manuela Parente[4] | Patrício Ramalhosa[1,12] | Paul Fofonoff[4] | Paula Chainho[2,13] | Ricardo Haroun[14] | Ricardo S. Santos[15] | Rogelio Herrera[16] | Tiago A. Marques[6,17] | Gregory M. Ruiz[10] | João Canning-Clode[1,10]

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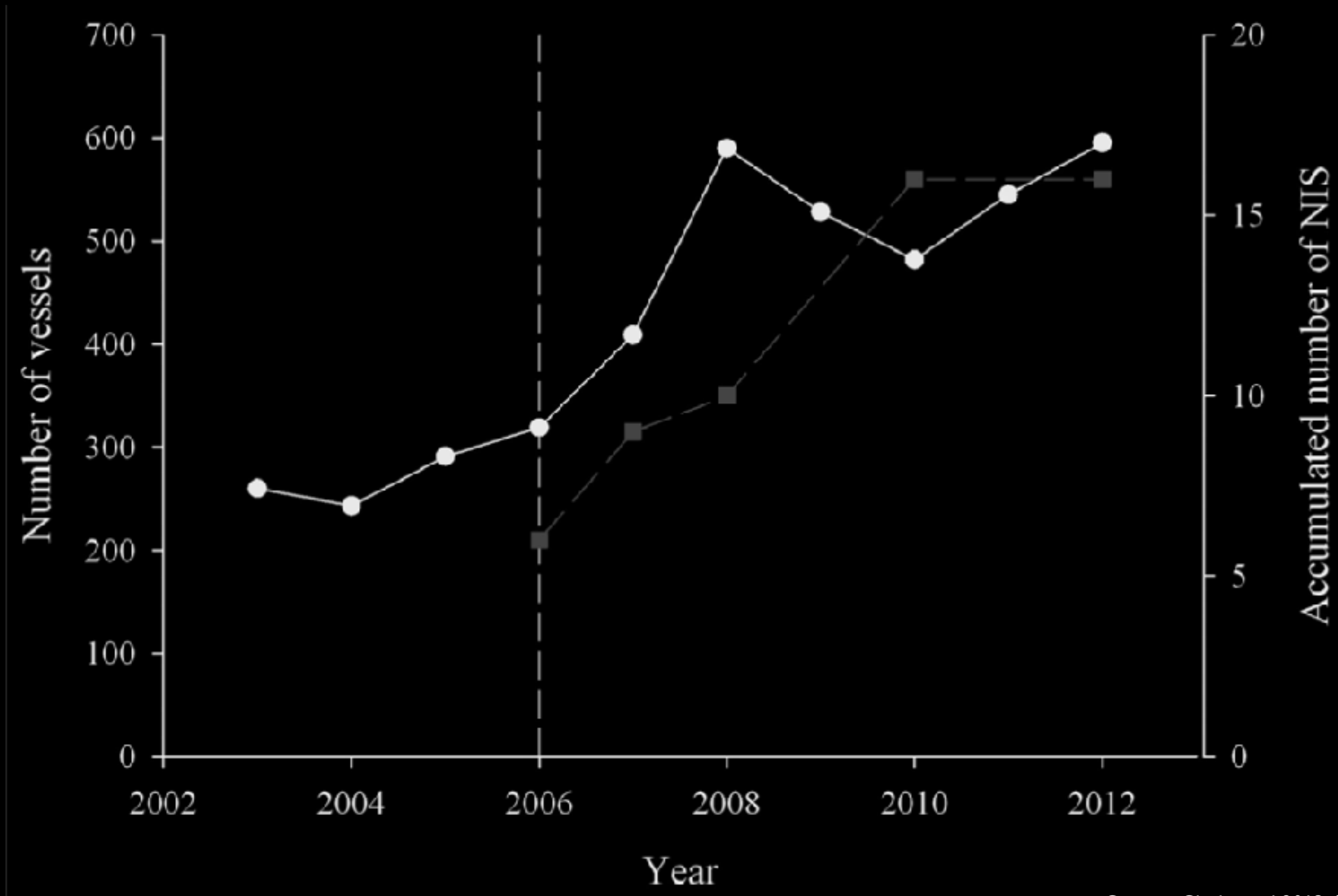
3 - Results

Ship traffic



Canning-Clode et al 2013, Aquatic Invasions

4 - Conclusions

- NIS > Canary Islands > Azores > Madeira > Cape Verde
- Closer island systems: Azores and Canaries, Madeira and Canaries, Madeira and Azores (shared NIS) → perhaps closer shipping history
- Cape Verde seems very distant from remaining island systems (NIS numbers and composition)
- Probably more NIS in all islands
- Search effort may play a role in these patterns

Castro et al., 2022

6 - Acknowledgements

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ICES
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