“GIS in Fisheries Management: Challenges and Prospects”

by

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What are the challenges to using GIS in fisheries research?

Challenges can best be examined under four main headings:

1. Intellectual and theoretical

2. Practical and organisational

3. Economic

4. Social and cultural

Within these broad areas are several sub-headings.

1. Intellectual and Theoretical Challenges

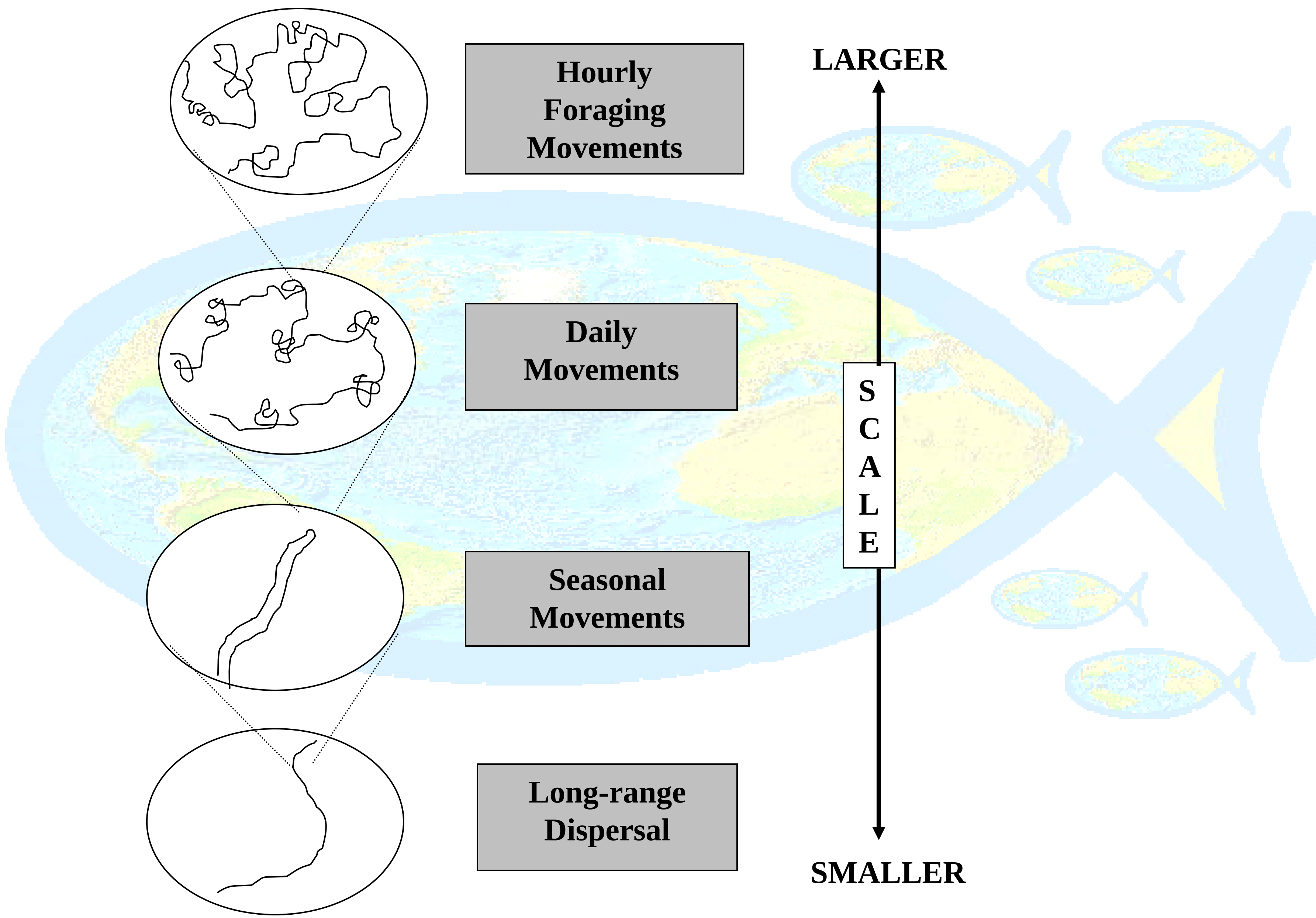
1.A. Mapping of moveable variables

In the ocean the environment and nearly everything in it moves.

Movements of water are caused by energy forces, e.g.:

- Wind > waves, advection currents
- Geostrophic > ocean circulation, gyres
- Gravitation > tides
- Hydrologic > river scour, discharge plumes

Some water movements can be easily predicted and measure so they can be modelled in a GIS – other movements are chaotic and are therefore difficult to model in a GIS.


Hourly
Foraging
Movements
Daily
Movements
Seasonal
Movements
Long-range
Dispersal
LARGER
SCALE
SMALLER

1.B. Multiple scale and resolution

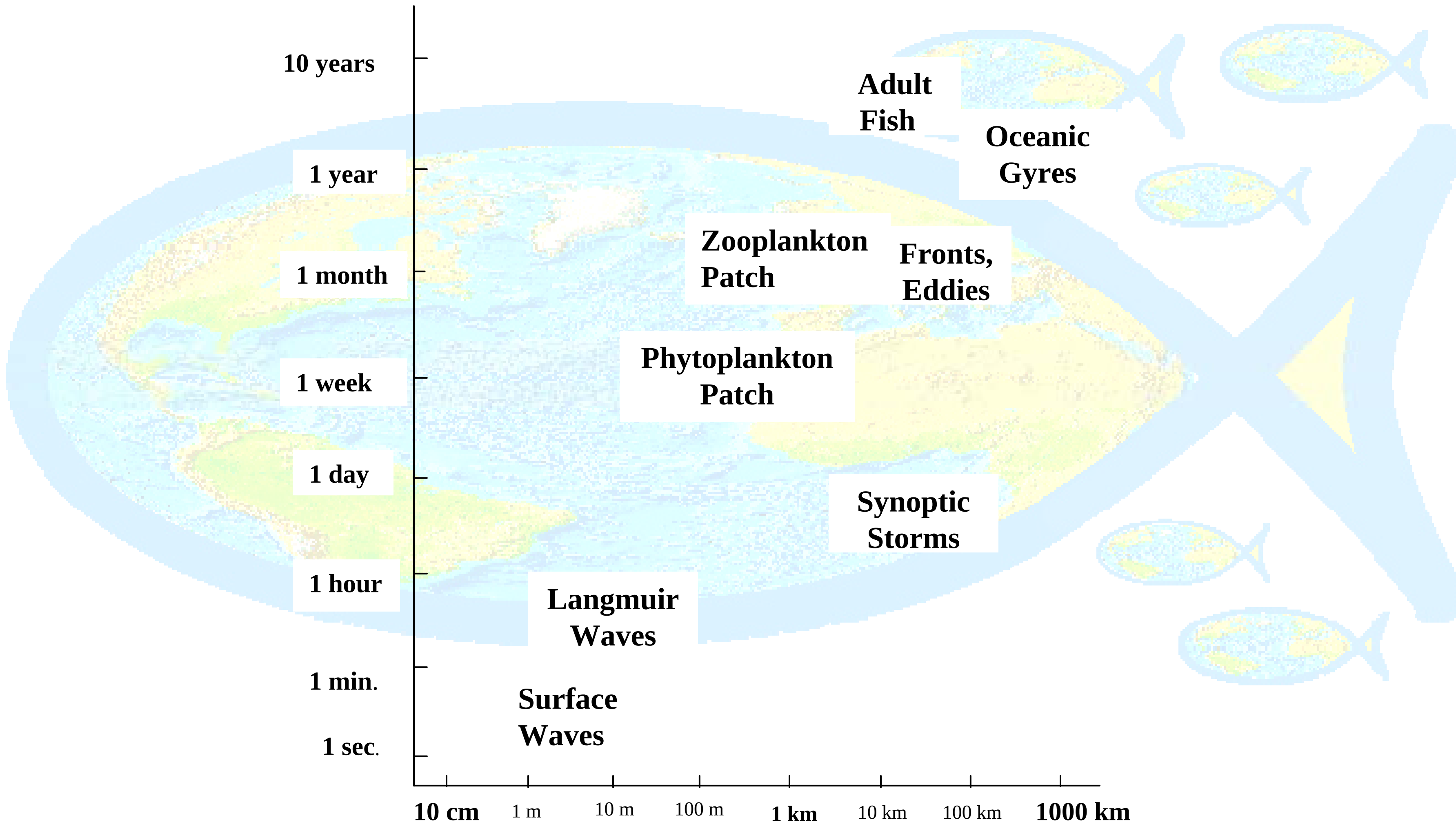
Within marine environments processes operate (or objects occur) at greatly varying scales.

Therefore careful thought must be given to the appropriate scale for any particular GIS task.

Resolution is best thought of in terms of spatial sampling frequency

There is a challenge both to identify a relevant scale and resolution, and then to develop a capability to operate the GIS at a range of scales.

Variable Scales of Fisheries and Oceanographic Processes



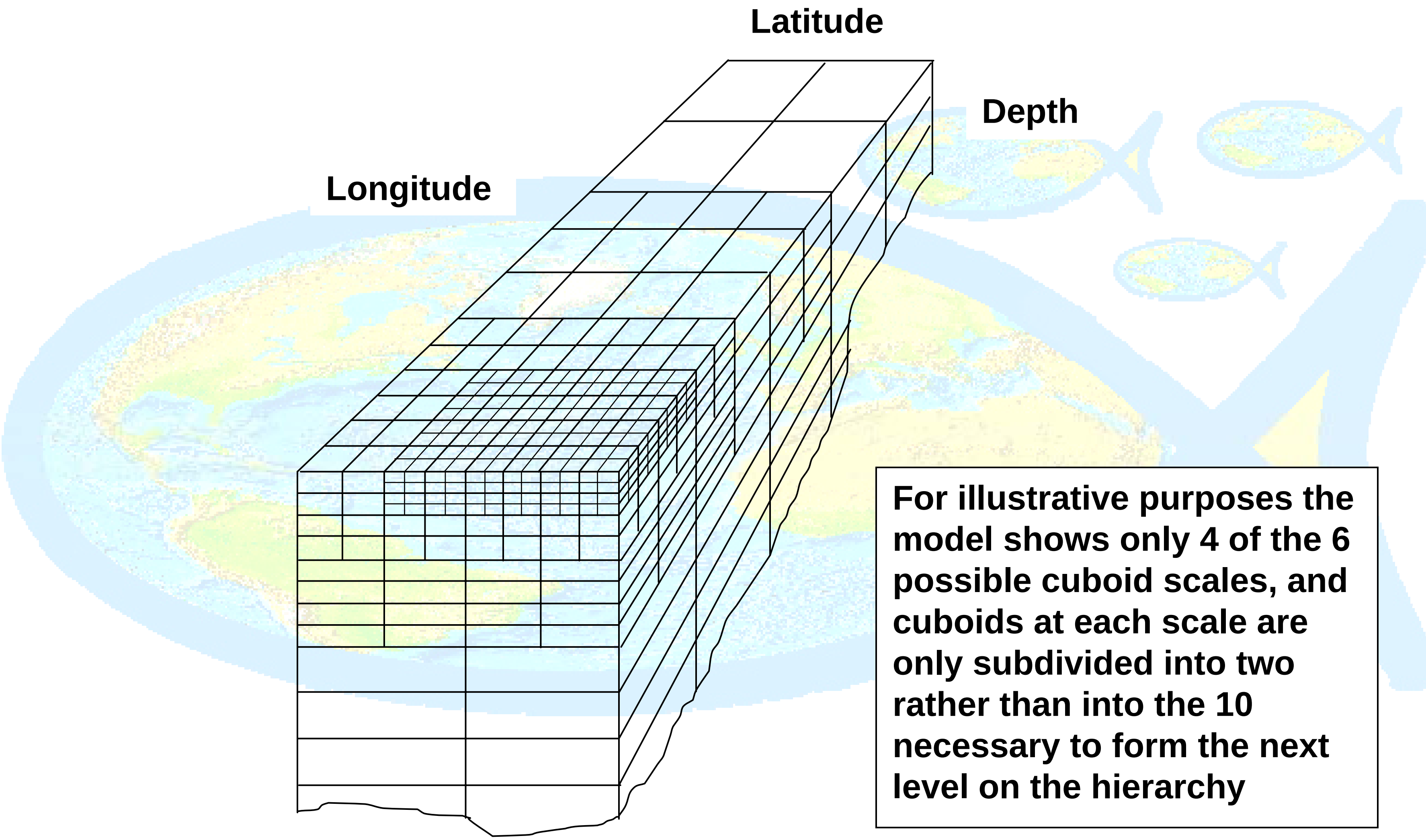
1.C. Handling 3 and 4 dimensions

The following diagram shows challenges associated with working in more than 2 dimensions. You can see that it might be desirable to divide 3D space into a number of resolutions. I suggest the following cuboid dimensions:

1. 10,000 x 10,000 x 1,000 metres
2. 1,000 x 1,000 x 100 metres
3. 100 x 100 x 10 metres
4. 10 x 10 x 1 metre
5. 1 x 1 x 0.1 metre
6. 0.1 x 0.1 x 0.01 metre.

What is the appropriate 3D resolution to work at?

A 3D Hierarchical Data Structure for the Division of Marine Space



For illustrative purposes the model shows only 4 of the 6 possible cuboid scales, and cuboids at each scale are only subdivided into two rather than into the 10 necessary to form the next level on the hierarchy

1.D. Developing specific marine GIS software

In terrestrial GIS's a single software package may be capable of a huge range of functions. But, most GIS's used in fisheries work only perform specific task related functions. Marine GIS's need to be multi-functional, i.e. because many spatial problems are varied and are inter-related.

Multi-functional marine GIS's could emerge from conversions of existing terrestrial software or from developing purposeful systems. Fully functional systems are emerging, e.g.

- ESRI (GIS vendor) has an active marine group working on this.
- Kiefer et al (University of S.California) has a system called EASY.
- Itoh and Nishida at the National Research Institute of Far Seas Fisheries has developed the 'Marine Explorer'.
- Etc.

1.E. The application of spatial statistics and models

Fisheries as a discipline has attracted an abundance of mathematical models and applications of spatial statistics.

Models may be explanatory or predictive.

GIS is well suited to providing an ‘activity surface’ for modelling.

1.F. Optimising of visualisation

Output from a GIS must be visually meaningful to users and decision makers. To achieve this there are challenges of:

- Classification in terms of numerical range
- Classification in terms of categorising variables
- The aesthetics of colour, fonts and symbology
- Map clarity
- Fuzzy boundary definitions
- Periodicy of mapping movements
- Portraying complex surfaces in map form, e.g. corals.

There are unlikely to be definitive answers to these challenges because individuals have visual preferences.

2. Practical Organisational Challenges

2.A. Data gathering

Although a challenge to all GIS work, data is especially difficult for marine fisheries. The reasons include:

- The size of the marine area
- Space/time resolution considerations
- Movement considerations
- Need to work in at least 3D
- Uncertainty of what data may be needed
- High costs of data collection
- Vessel availability
- Weather considerations
- Sampling strategies
- Time availability

Huge efforts may be needed to assemble a limited range of data.

2.A. Secondary Data

The use of secondary (processed) data may be possible but it might suffer from:

- Inappropriate space/time resolution
- Being specific to a particular data collection event
- Having inappropriate classification or categories
- Having the wrong format or data structure
- A lack of metadata information
- Not being readily located or afforded.

Although lots of data is available via the Internet, this author has yet to download a single piece of useable data!

2.B. Subject organisation

The subject area of fisheries is concerned with:

- environmental and fisheries science and management;
- biology;
- meteorology;
- oceanography
- various technologies.

The subject is pursued by a huge range of small and dispersed institutions, usually occupying peripheral, coastal locations.

This means that the subject area can be very fragmented, e.g. there may be many small projects going on, with low budgets, with a lack of cohesion of aims, and perhaps much duplication.

2.C. Information Output

Here the concern is with the dissemination of GIS-related information on fisheries, and with the distribution of GIS-based information.

Because GIS is simply a tool to help fisheries managers, researchers, oceanographers, etc, it does not merit a specific dedicated journal. Most GIS applications work gets published in the ‘grey’ literature.

There are relatively few workshops, conferences, symposia.

Very few books have been published.

3. Economic Challenges

Challenges relate to the costs of fisheries and oceanographic GIS work, plus obtaining funds to cover these costs.

Although computing hardware and software costs have decreased, data costs have risen significantly both in real terms and as a proportion of total costs.

In developing countries the cost problem is very significant - most GIS’s cannot operate without donor support.

Funding may be hard to obtain because it is difficult to demonstrate cost:benefit advantages for a GIS.

Fishing is typically an activity associated with poorer sections of society.

However, it is likely that the plight of the world’s fisheries are now so bad that required funding may now be more forthcoming.

4. Social and Cultural Challenges

4.A. Overcoming technological inertia

Overcoming technological inertia is very understandable (I am the last person in the UK without a cell phone!!), and it might be related to the cultural ambience of the company, organisation, region, etc.

Efforts to implement GIS may be difficult because it has no one to promote it.

There is not a wide-spread recognition that most problems relate to dis-equilibrium in space.

The biggest challenge may be in keeping up with changes in GIS methodologies and techniques, especially when these are allied to accelerating changes in fisheries caused by human predation and by global climatic change.

4.B. Developing geographic cognition

The challenge here is in having an appreciation of the geographic aspects of a problem, plus having an understanding of geographic relationships and the ability to comprehend geographic inputs, analyses and outputs.

Geographic expertise involves the recognition of spatial relationships in terms of adjacency (being next to), distributions, heterogeneity or homogeneity, etc.

Visual discrimination is a vital tool (or ability) in seeking out subtle relationships. Possible flows and interactions must be recognised and understood, as must spatial patterns, trends and zones.

In other words, there is a great art in being a geographer – being able to interpret spatial relationships.

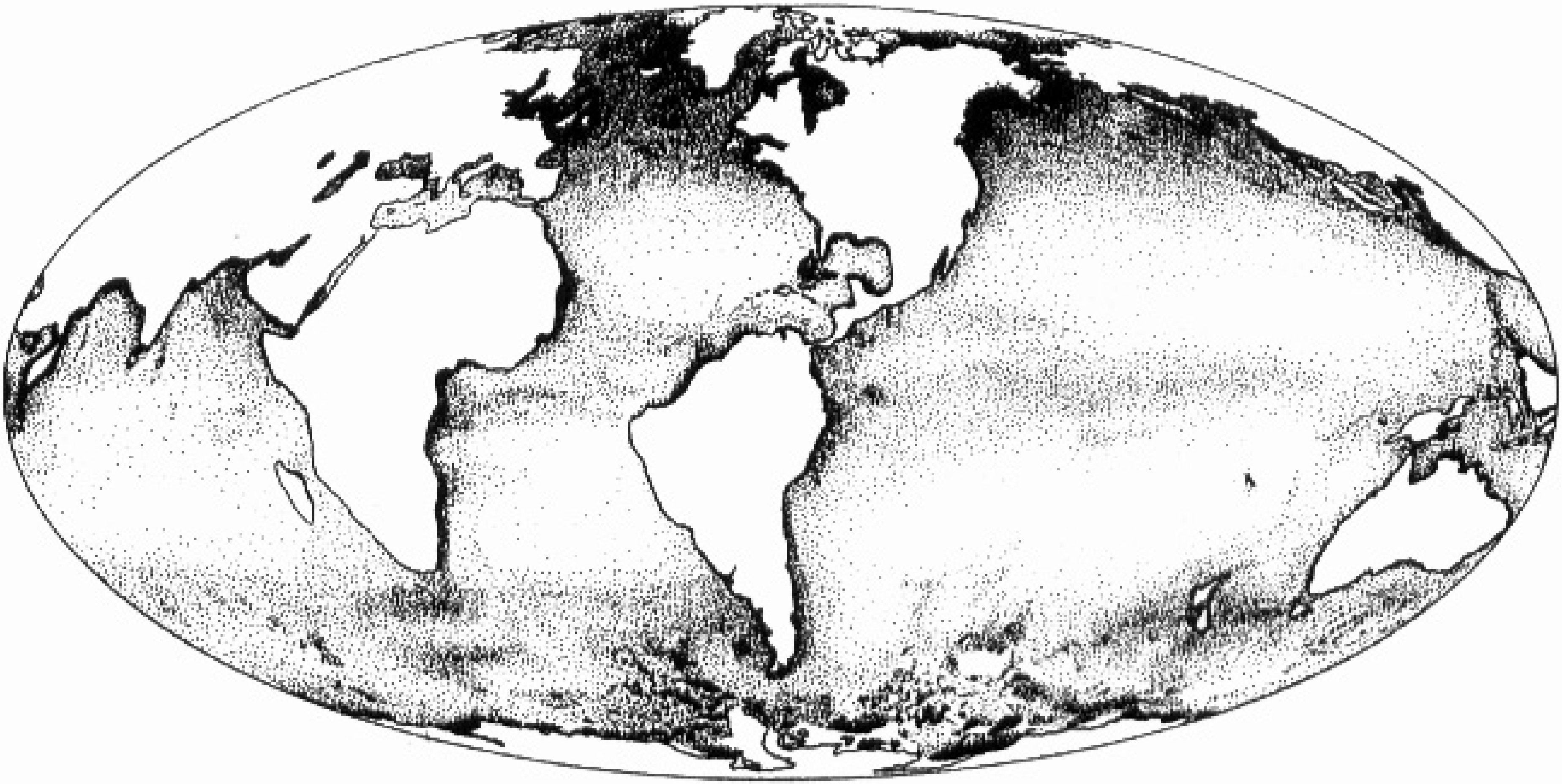


Figure 1. The first global view of the geographical distribution of the production of plants

Prospects for Fisheries GIS

Potential analyses performed by a fisheries GIS include:

• Modelling the relationship between species abundance and the physical environment.

• Establishing predator-prey relationships.

• Monitoring factors relating to experimental fishing programs.

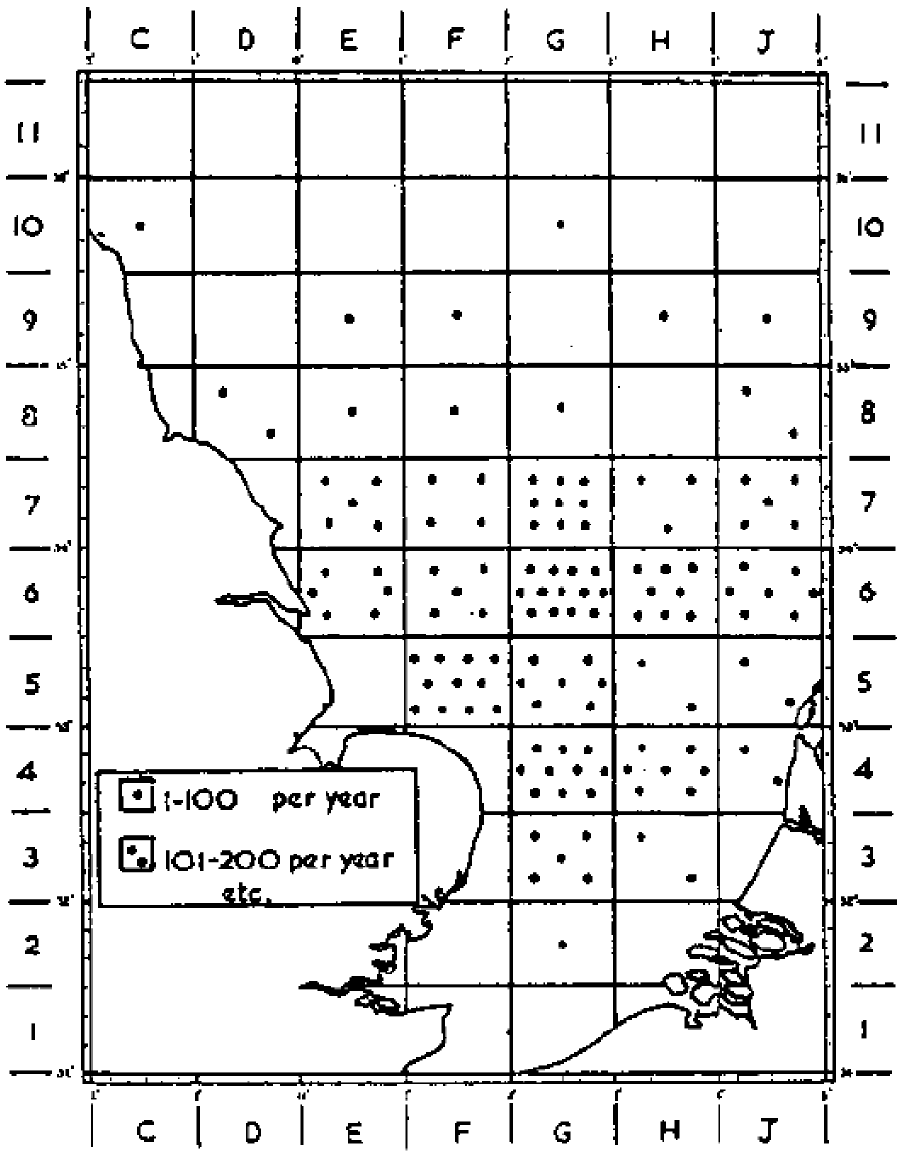
• Analysing spatial variability in fish community structure.

• Analysing relationships between bottom ecology and trawl tow lines.

• Selecting locations for marine stock enhancement.

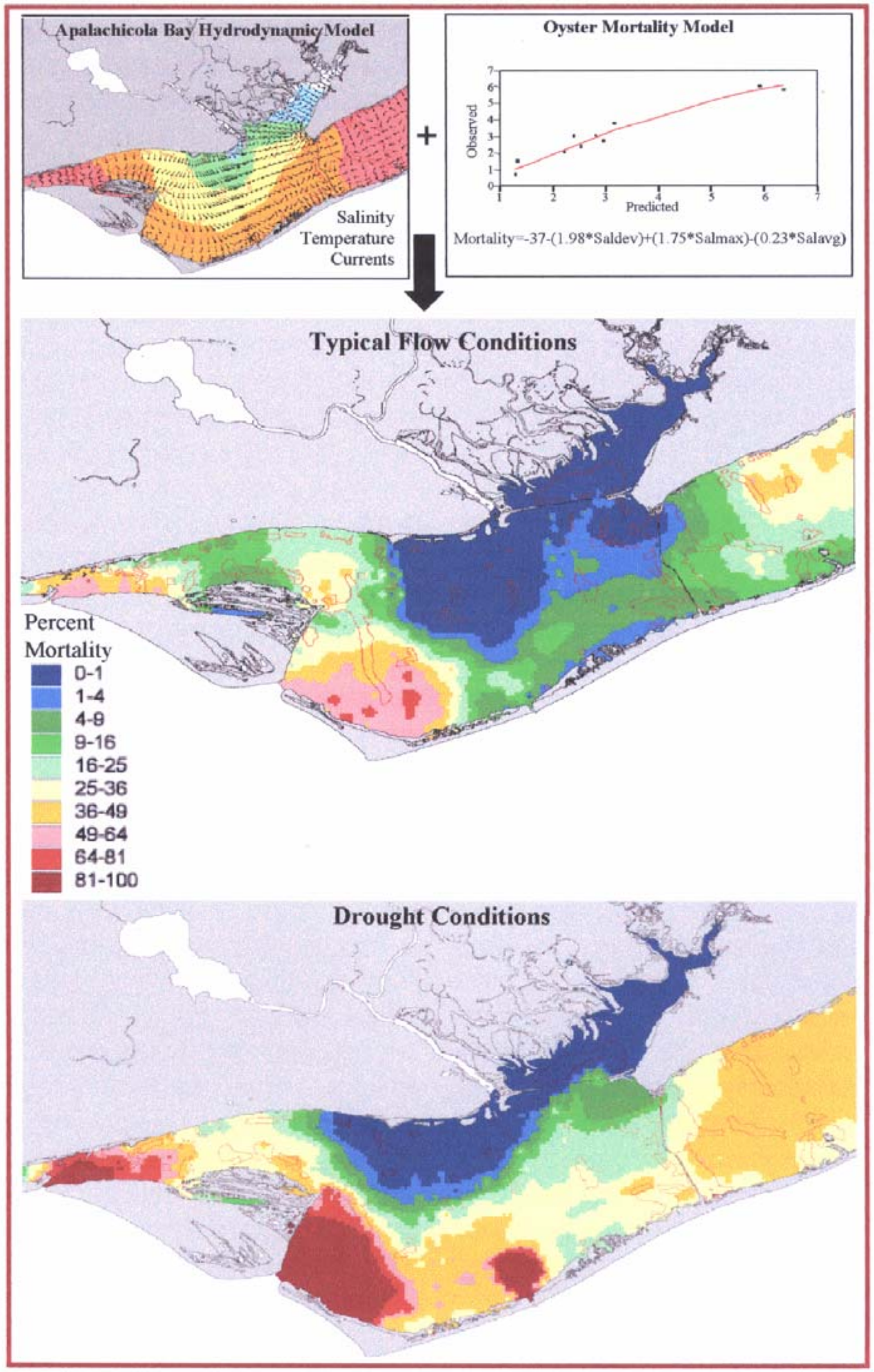
• Analysing the performance of catch or of effort quotas.

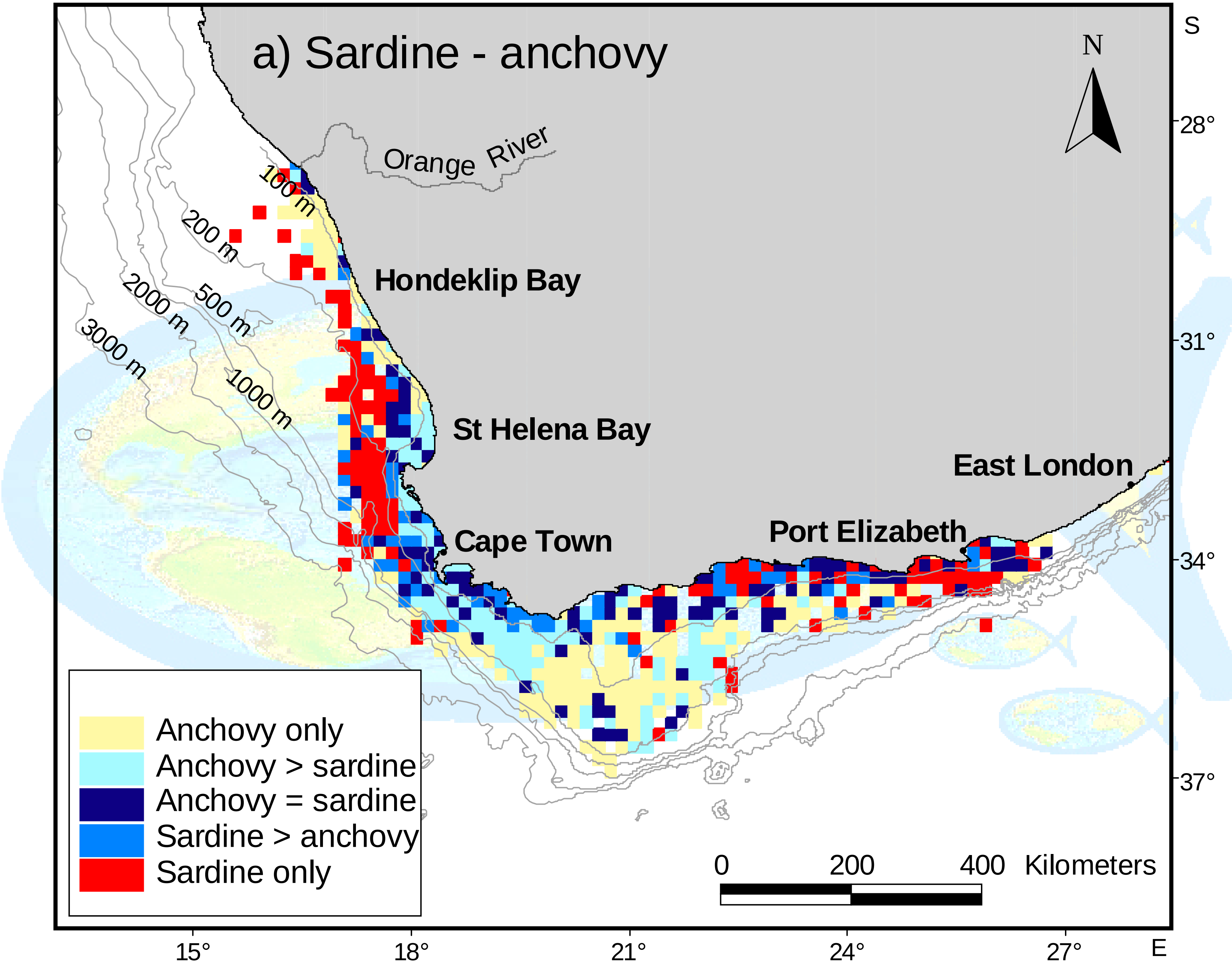
• Identifying optimum habitats or areas for marine conservation.



From Beverton & Holt (1957) showing the origin of plaice otoliths collected in a North Sea survey

Modelling the potential oyster mortality in Apalachicola Bay, Florida, under different fresh water input conditions





a) Sardine - anchovy
N
Orange River
100 m
200 m
500 m
1000 m
2000 m
3000 m
Hondeklip Bay
St Helena Bay
Cape Town
Port Elizabeth
East London
S
28°
31°
34°
37°
15°
18°
21°
24°
27°
E
Anchovy only
Anchovy > sardine
Anchovy = sardine
Sardine > anchovy
Sardine only
0
200
400
Kilometers

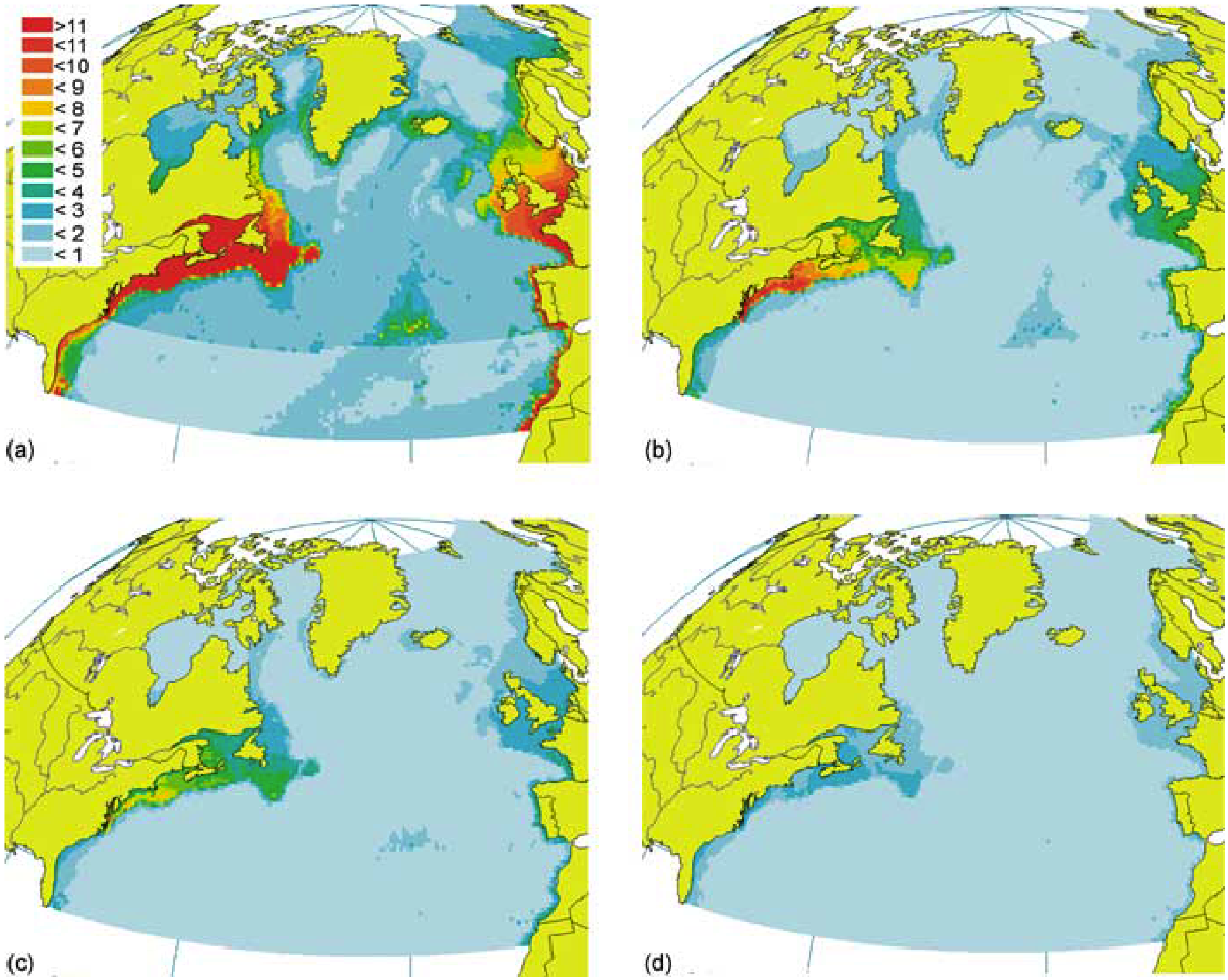
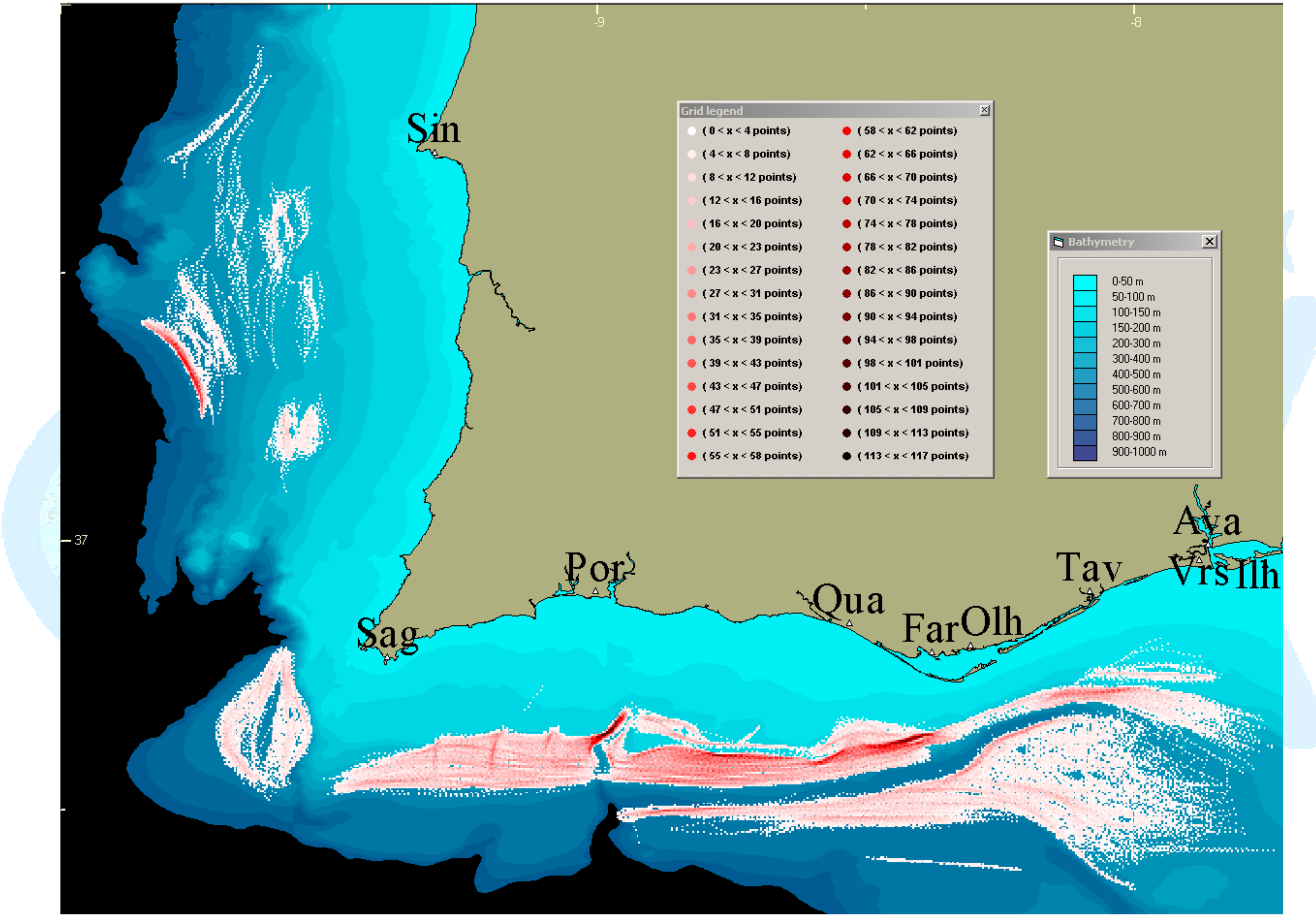
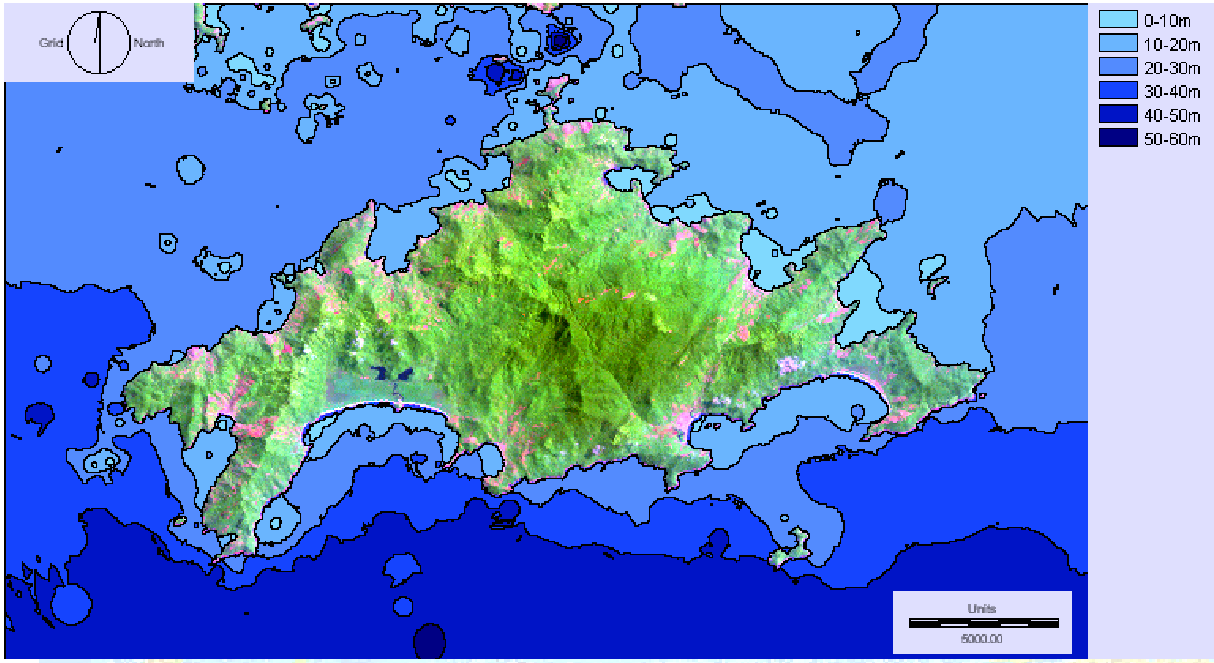


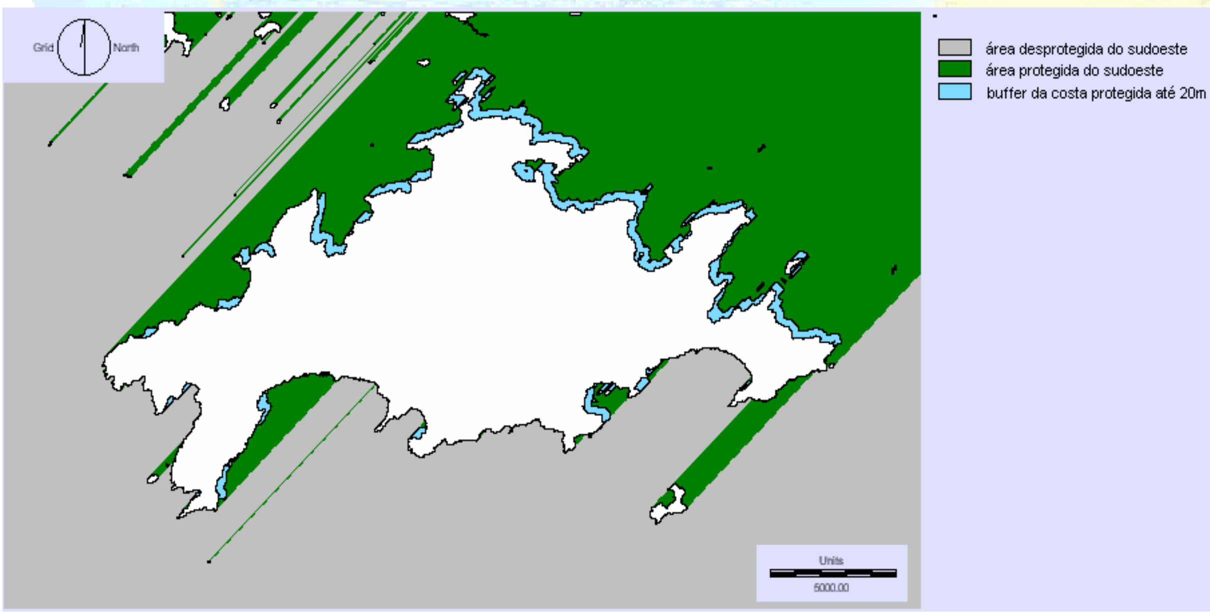
Figure 7 Biomass distributions for high-trophic level fishes in the North Atlantic in (a) 1900 (b) 1950 (c) 1975 and (d) 1999. The distributions are predicted from linear regressions based on primary production, depth, temperature, year, ice cover, latitude and catch composition. Units for the legend are tonnes km^{-2}.



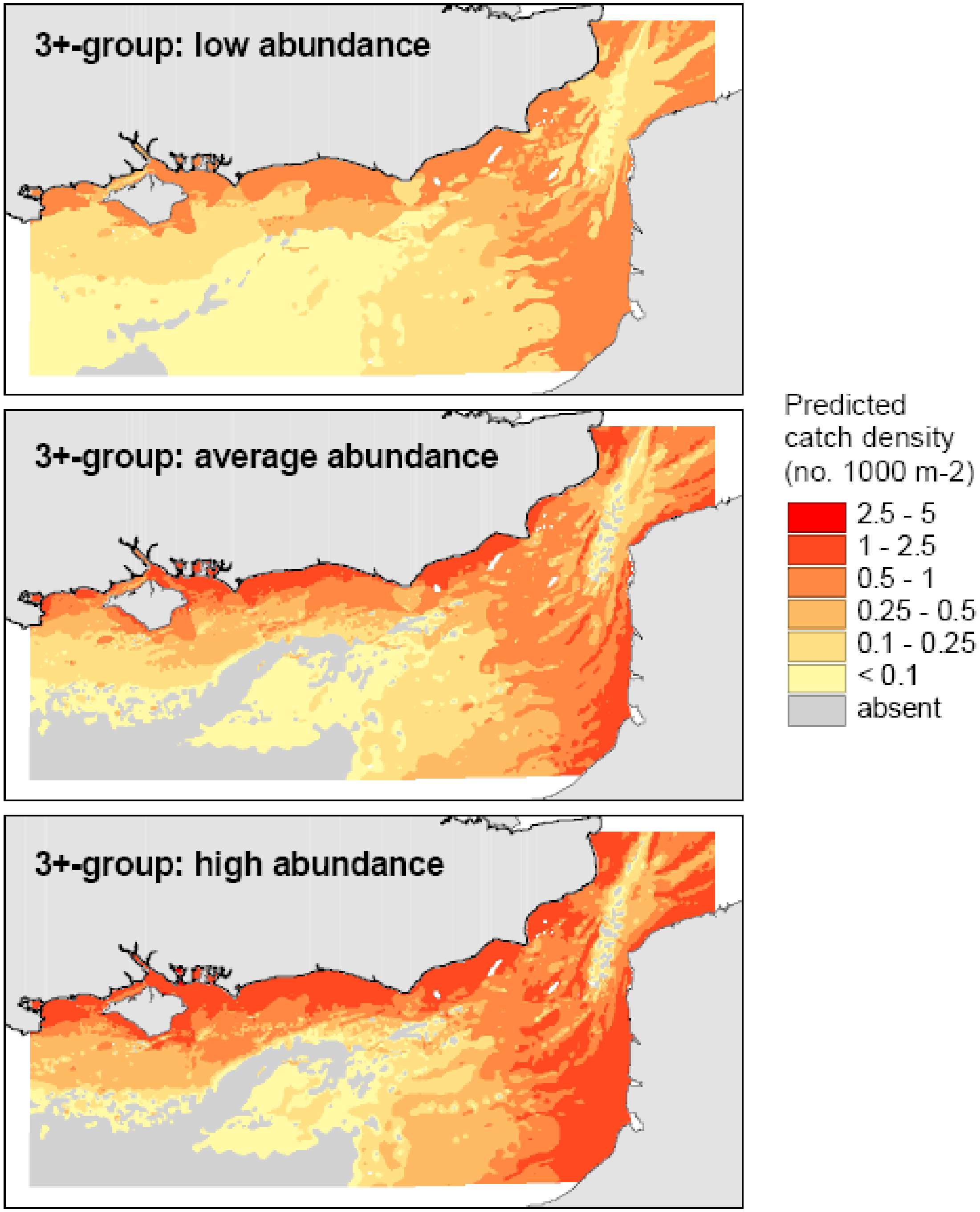
Fishing effort in the SW Portuguese crustacean trawl fishery (2003) as registered by VMS location data



(a) Bathymetry around Ilha Grande, Rio de Janeiro, Brazil

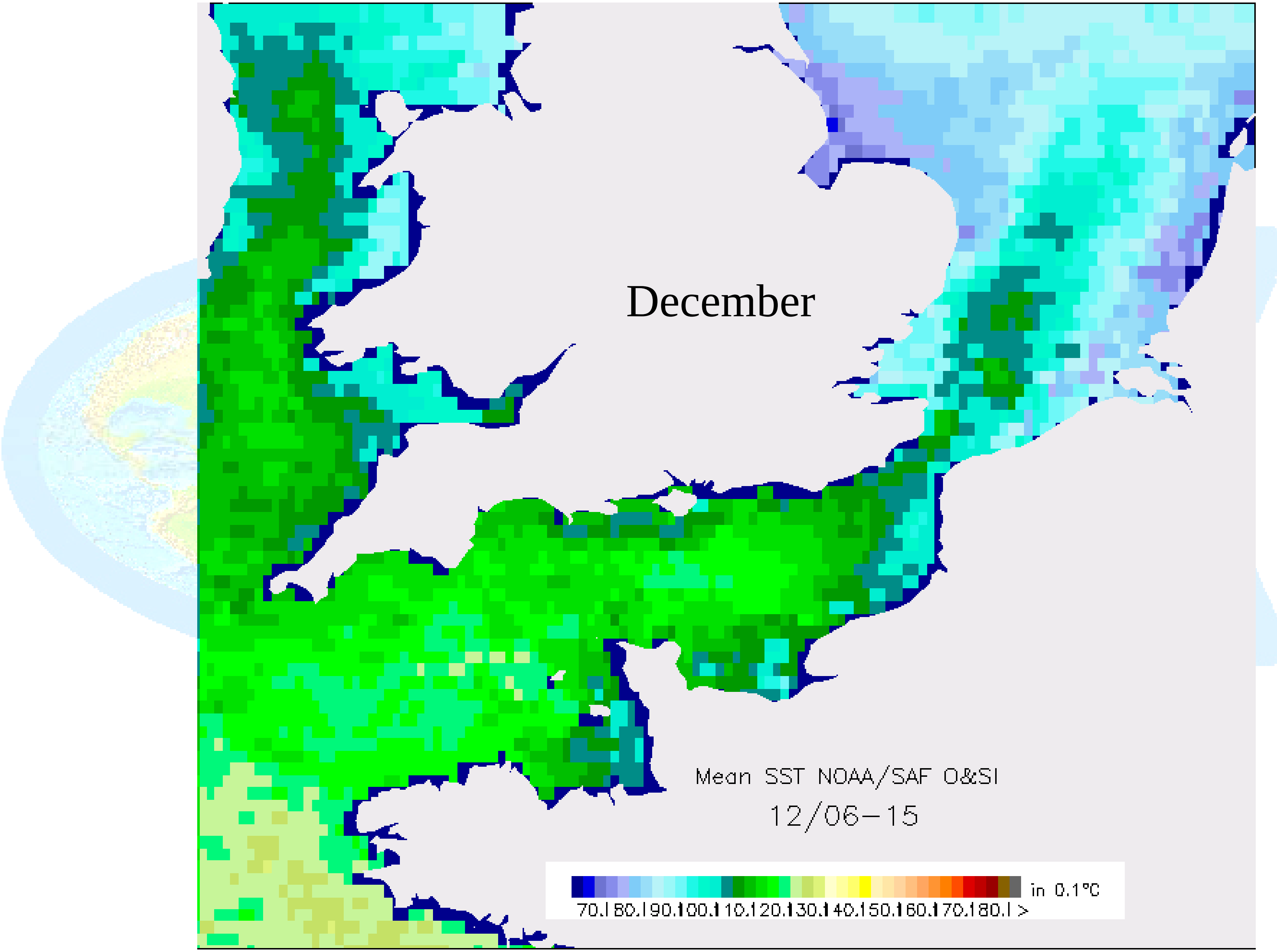


(b) area of Ilha Grande protected from the SW wind and optimum habitats for sea cucumber exploitation.



Predicted catch densities for adult (+3) sole (*Solea solea*) during years of high, average and low population abundance in the English Channel

Decadal mean of sea surface temperature - 1st of each month



Areas for Major Progress in Fisheries GIS

- Applications of Geo-statistics
- Development and use of 3/4D databases
- Development and use of ‘animated’ GIS
- Further development of fisheries GIS specific software
- Greatly increased funding available for fisheries/GIS projects
- Better organisation of access to marine and fisheries data
- Increase in international cooperation, including conferences, workshops, research projects and publications
- GIS increasingly being absorbed into fisheries research and management without explicit reference.