Instituto Português do Mar e da Atmosfera

2017

# EO for Fisheries and Aquaculture

## Facts and Gaps

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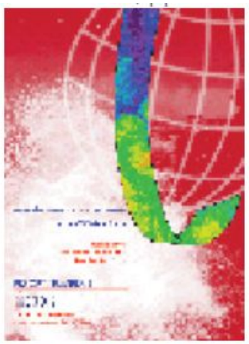
IPMA

Linking Earth Observation data and Sustainable Development across the Atlantic.
03 - 05 December 2019, Estoril, Portugal

# Selected topics

*Remote Sensing in Fisheries and Aquaculture.* Edited by Marie-Hélène Forget, Venetia Stuart and Trevor Platt, pp. 120



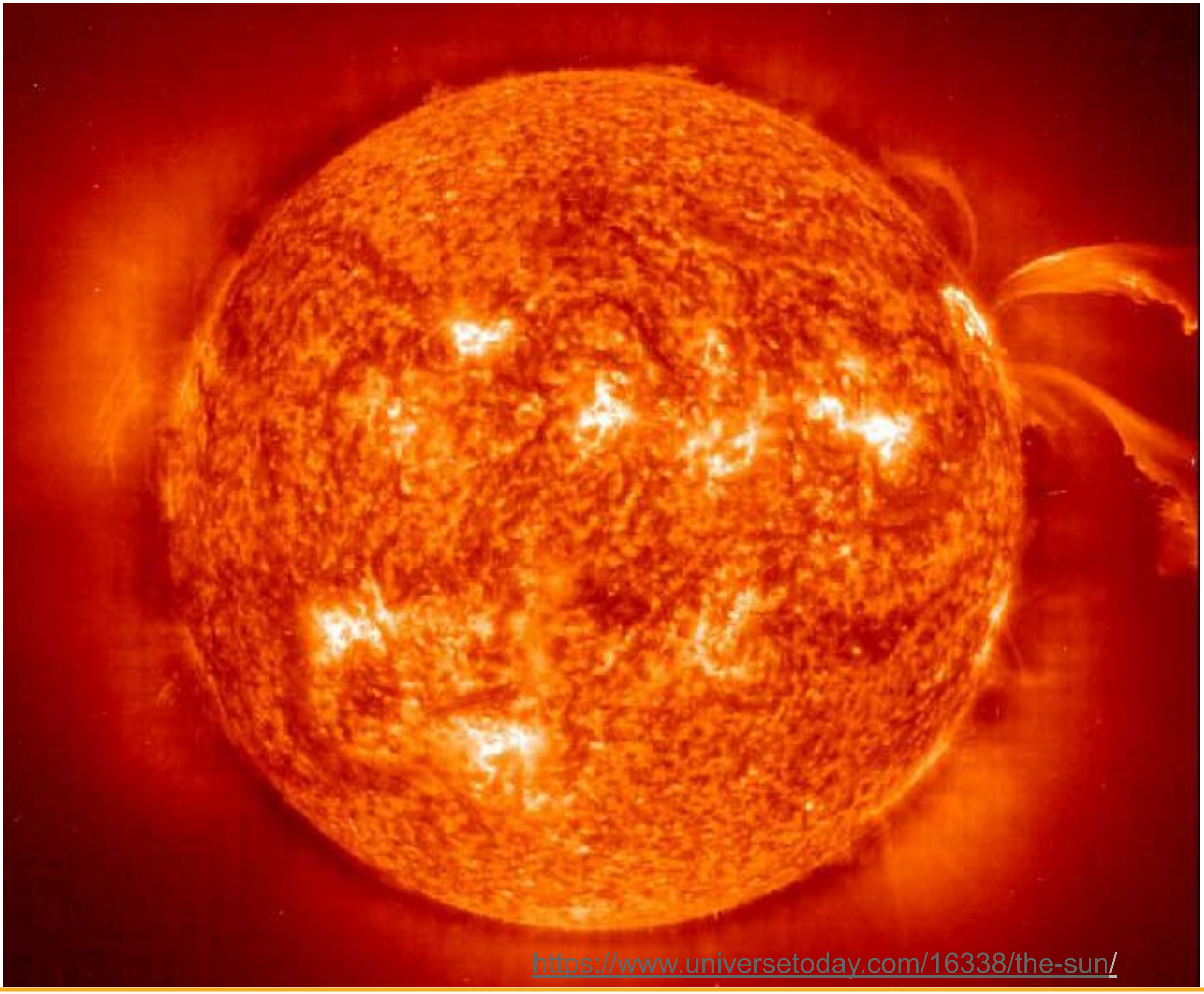
**IOCCG Report 8 (2009)**

- Remote Sensing (RS) and Ocean Ecosystems (Intro)
- Fisheries Oceanography
  - from plankton to fish
  - end-to-end models
- RS Applications in Stock Assessments / Ecosystem-based Management
  - Cushing’s match/mismatch hypothesis
  - ‘Parental condition’ hypothesis
- Remote Sensing Applications in Marine Aquaculture
  - site selection
  - culture modelling
  - HABs

- Remote Sensing in Fisheries and Aquaculture. Eds M.-H. Forget, V. Stuart and T. Platt, 2009. IOCCG Rep.8

Hardman-Mountford et al., 2009 (Ch.1)

# The source of energy for the ecosystem is the sun

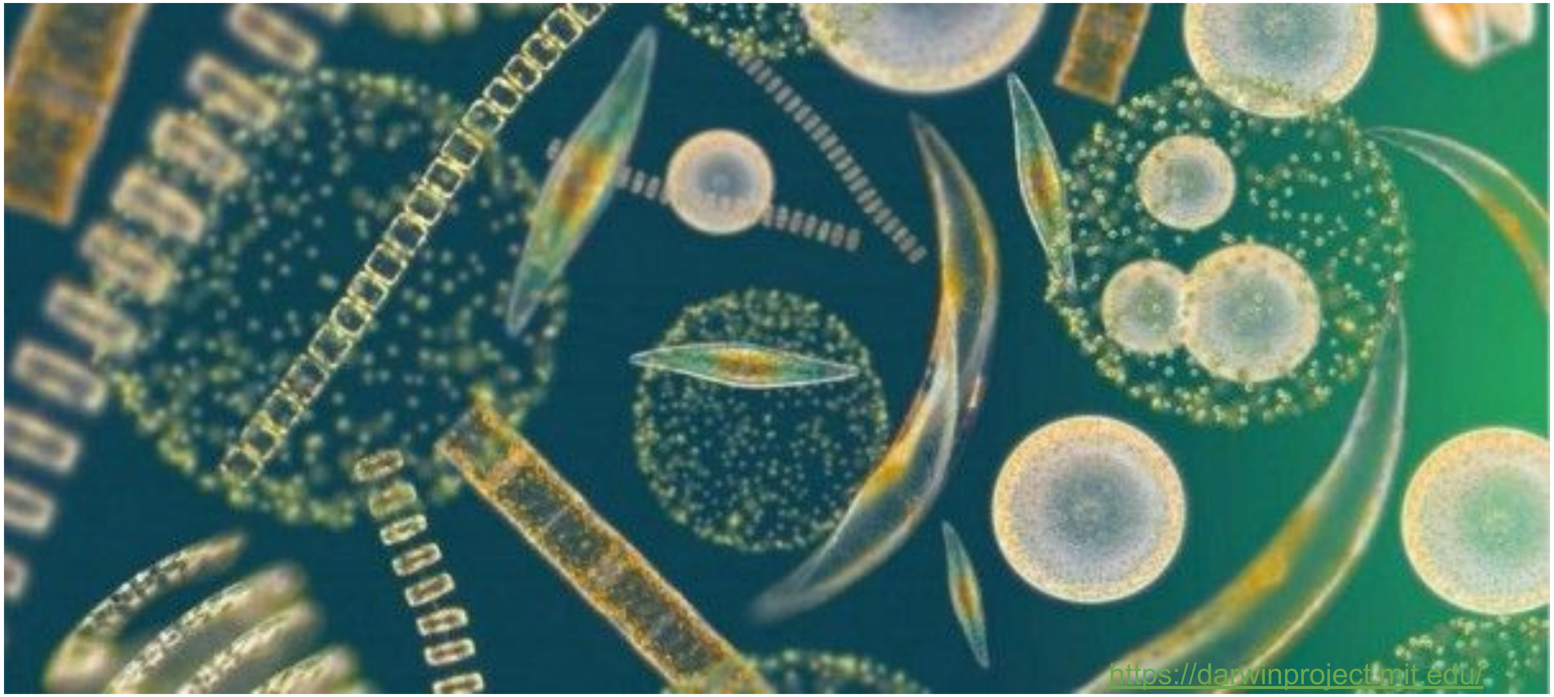


https://www.universetoday.com/16338/the-sun/

- Remote Sensing in Fisheries and Aquaculture. Eds M.-H. Forget, V. Stuart and T. Platt, 2009. IOCCG Rep.8

Hardman-Mountford et al., 2009 (Ch.1)

In aquatic systems, the solar input is captured and made biologically available by the photosynthetic pigments within phytoplankton



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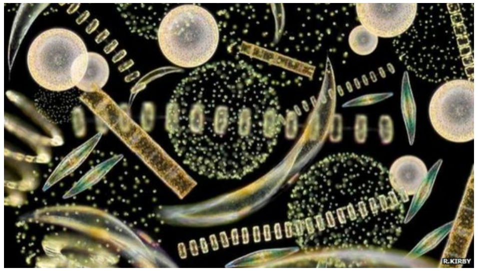
Hardman-Mountford et al., 2009 (Ch.1)



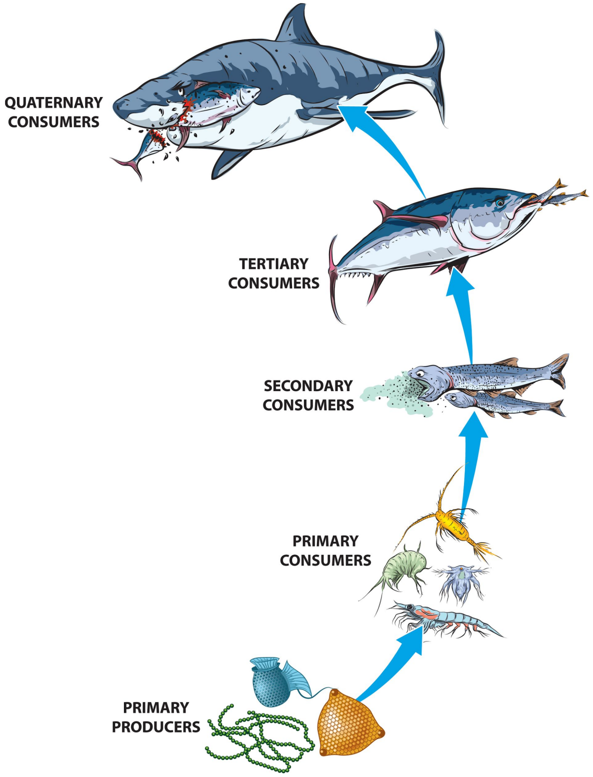
https://www.bbc.com/news/science-environment-35631223

Phytoplankton are (... vulnerable) to environmental fluctuations. The productivity, biomass, size-distribution, community composition and seasonality are all determined by the ambient physical conditions, which vary on hourly, daily, seasonal and interannual timescales.


https://darwinproject.mit.edu/

- Remote Sensing in Fisheries and Aquaculture. Eds M.-H. Forget, V. Stuart and T. Platt, 2009. IOCCG Rep.8

Hardman-Mountford et al., 2009 (Ch.1)




Because the base of the aquatic food chain (phytoplankton) is hostage to the weather and the climate
(...) environmental fluctuations will propagate through the phytoplankton to higher trophic levels.

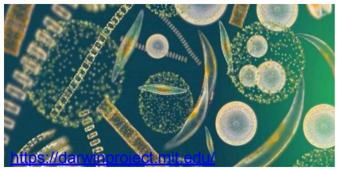
http://kidspressmagazine.com/science-for-kids/misc/misc/marine-food-chain.html

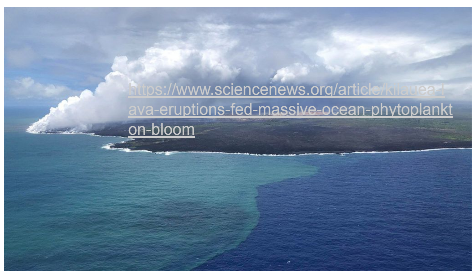
- Remote Sensing in Fisheries and Aquaculture. Eds M.-H. Forget, V. Stuart and T. Platt, 2009. IOCCG Rep.8

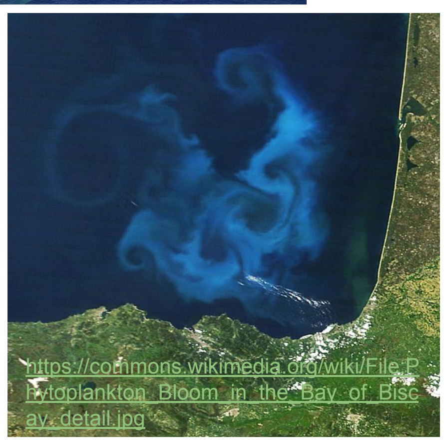
Hardman-Mountford et al., 2009 (Ch.1)

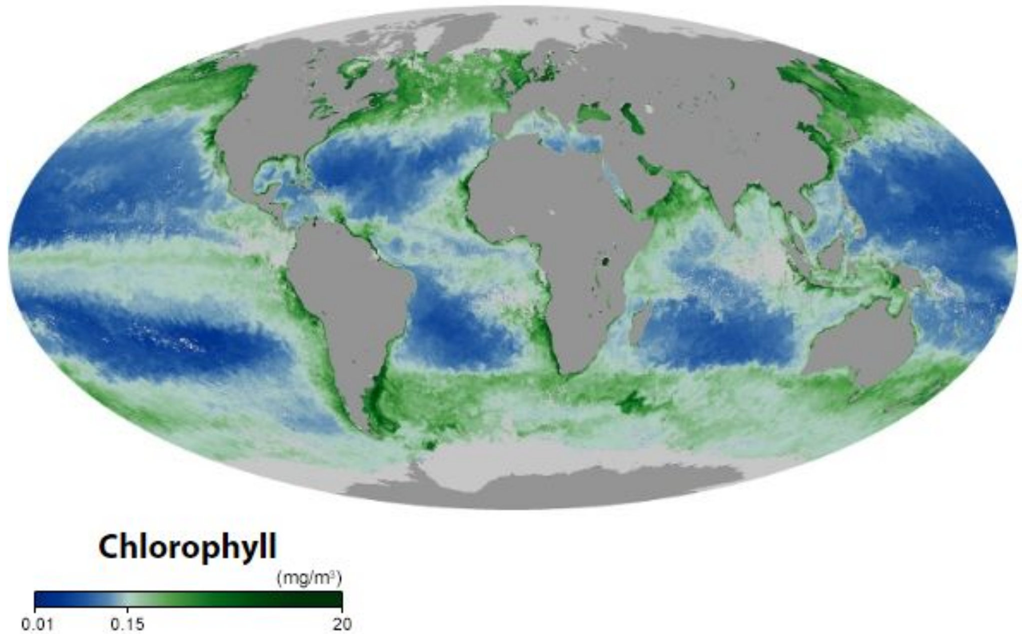
… good news...

(...) the presence of <u>pigments</u> in phytoplankton, that enables us to map the <u>colour of ocean</u> waters, hence the abundance of phytoplankton.




https://earthobservatory.nasa.gov/global-maps/MY1DMM_CHLORA

# Fisheries Oceanography:
# Linking Physical Oceanography, Phytoplankton and Fish

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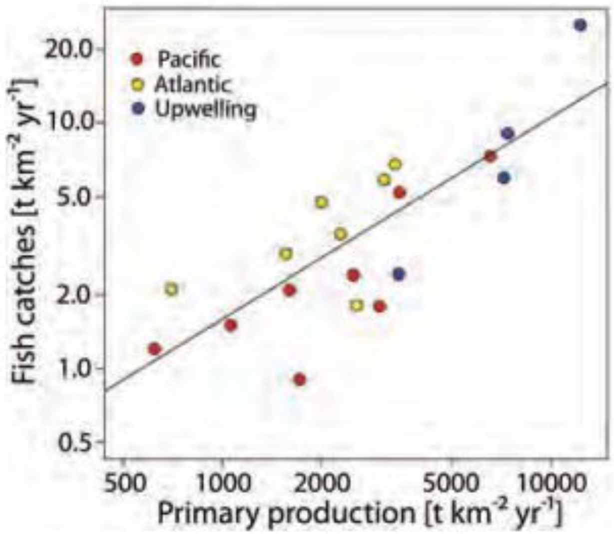
Four broad approaches:

- statistical models
- size spectra models
- energy mass-balance models
- ‘end-to-end’ or ‘physics-to-fish’ ecosystem models

(...) prevailing view (...) that bottom-up processes control the abundance and biomass of high trophic level organisms, notably through the level and variability of primary production at the base of the food web.

(...) Positive relationships between primary production (or annual mean chlorophyll-a concentration used as a proxy for primary production) and long-term average fishery catches have been described




(Dulvy et al., 2009, Fig.2.2)
The relationship between fishery landings (catches) and primary production in a range of large marine ecosystems (Redrawn from Ware, 2000).

End-to-end models (...) are founded on first principles and aim to represent accurately the dynamic physical forces affecting oceans (...) and their effects on primary and secondary production.

(...model development) is a key challenge for assessing the combined impacts of fishing and climate changes on marine ecosystem structure and functioning.

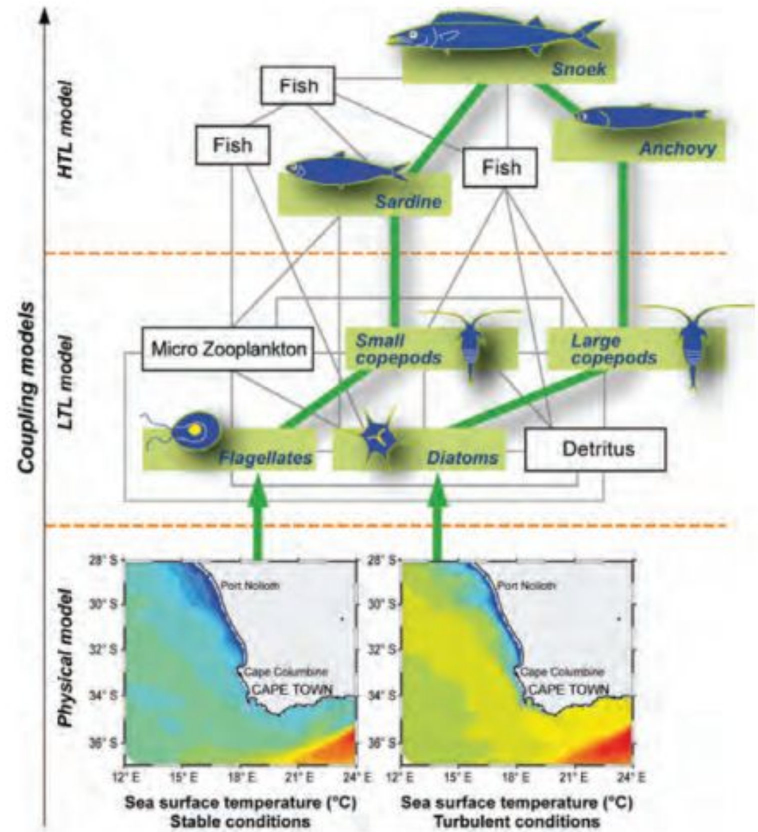



**Figure 2.12** End-to-end models can be built by coupling physical atmospherically forced hydrodynamic models to models of lower trophic levels (pelagic and benthic) to high trophic level fish production models (Cury *et al.*, 2008). The boxes represent key species or groups of species, the lines represent the trophic interactions (pathways) and the arrows represent the forcing of hydrodynamic models on the lower trophic level model. (Adapted from Cury *et al.*, 2008).

# Cushing’s match/mismatch hypothesis - Haddock recruitment - Nova Scotia

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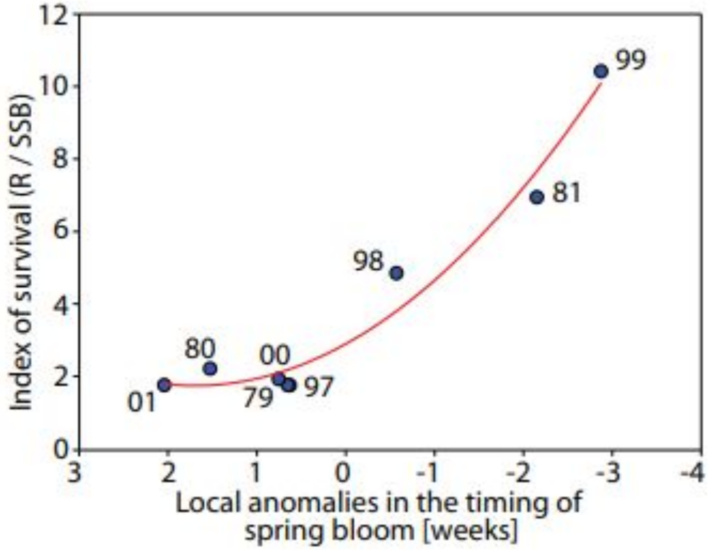


**Figure 3.6** Index of haddock survival on the Scotian Shelf (recruitment index normalised by spawning stock biomass) versus satellite-derived anomalies in the timing of the spring phytoplankton bloom.

(1981 and 1999) (...) correspond to years in which the spring phytoplankton bloom was exceptionally early (Platt et al., 2003) (...) early blooms favour higher haddock recruitment.

**Early spring bloom => Enhanced survival on those larvae produced early in the spawning period**

# ‘Parental condition hypothesis’ - Georges Bank haddock

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Friedland et al. (2008; 2009)

(...) fall phytoplankton bloom the year prior to spawning (...) highly correlated with subsequent recruitment

fall bloom affects recruitment through **enhanced feeding** conditions for adults and the resultant increase in the **quantity and quality** of their reproductive output.

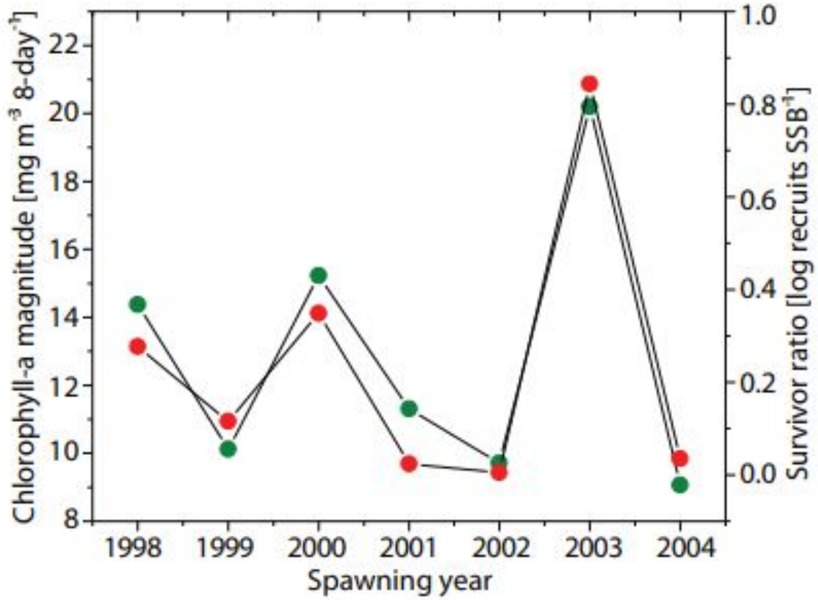


**Figure 3.7** The magnitude of the fall bloom on Georges Bank the year before spawning (green dots), and the survivor ratio of the year class spawned during the spawning year for the Georges Bank stock of haddock (red dots). Chlorophyll magnitude is a bloom index that reflects the concentration and duration of the fall phytoplankton bloom. The survivor ratio is the ratio of recruitment to spawning stock size, which corrects for the spawning stock size effect.

ICES (2016) sees Ecosystem Based Management (EBM) as the **primary approach** for the management of the human activities affecting the ecosystems and Ecosystem Based Fisheries Management (EBFM) as a constituent part of the management addressing the fishing sector.

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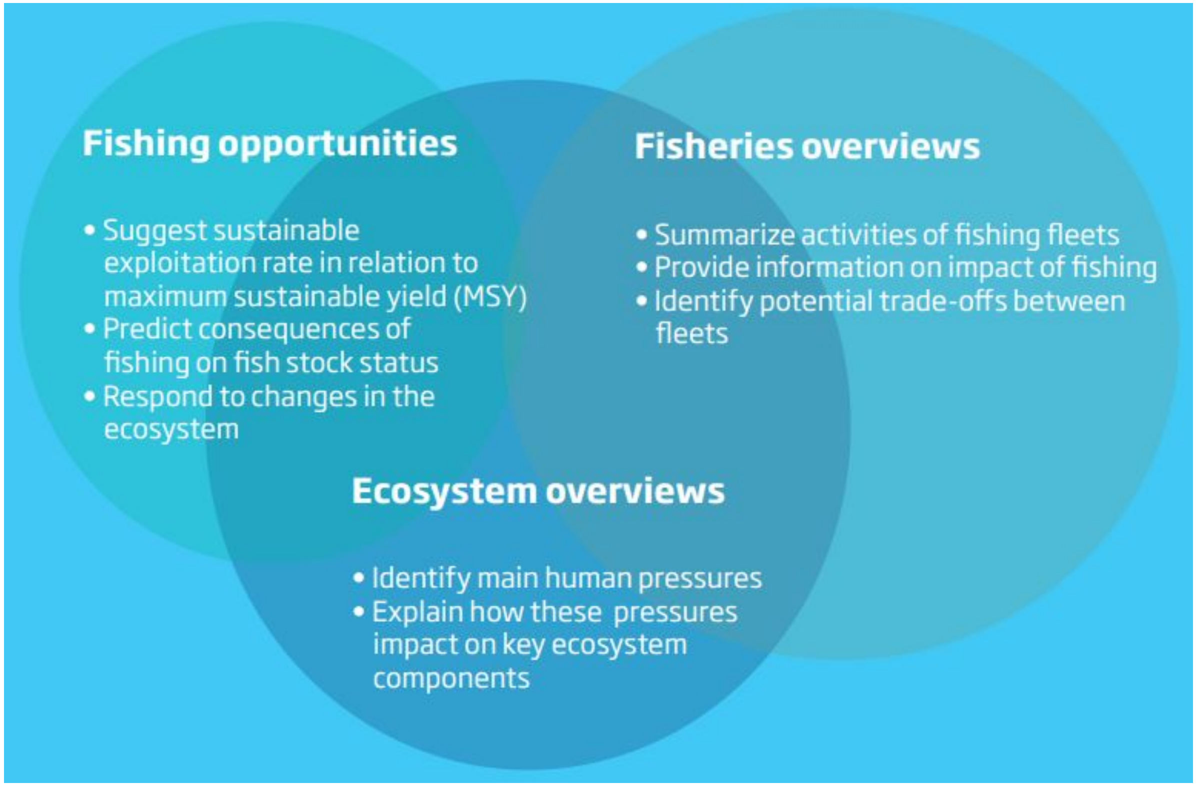


https://www.ices.dk/explore-us/Documents/EBFM%20final%20version.pdf

- Remote Sensing Applications in Marine Aquaculture
  Grant et al., 2009

IOCCG Rep.8, 2009

## RS potential for fish and shellfish farming

(...) In contrast to land-based aquaculture planning (...) site selection in open seas requires extensive use of medium-resolution images (...) for the analysis of the seasonal and interannual variability of the highly-dynamic characteristics of the marine environment, and also for the determination of environmental patterns and trends of potential aquaculture sites, or for the preparation of aquaculture suitability maps.

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- Site selection
- Production capacity / Culture modelling
- HAB detection / development

# Site selection

Petersen et al., 2016

https://doi.org/10.1007/s10499-015-9953-0

**Table 6.1** Criteria for fish-cage site selection and environmental monitoring in Spain, in the Mediterranean Sea (adapted from JACUMAR, 2008).

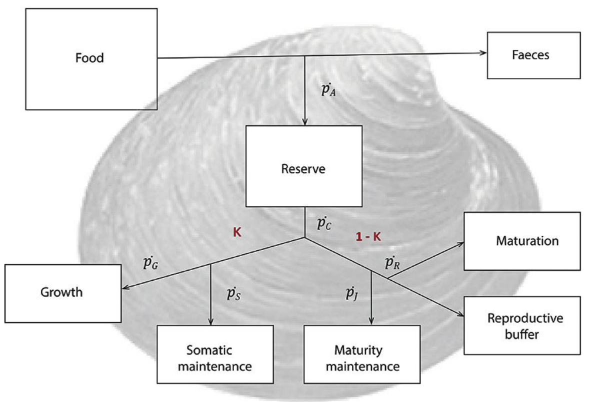
| Variable | Good | Medium | Bad |
|---|---|---|---|
| Coastal exposition | Partial | Sheltered | Non-sheltered |
| Wave height (m) | 1 to 3 | < 1 | > 3 |
| Water depth (m) | > 30 | 15 - 30 | < 15 |
| Water current speed (cm $s^{-1}$) | > 15 | 5 - 15 | < 5 |
| Pollution level | Low | Medium | High |
| Max. Temperature (°C) | 22 - 24 | 24 - 27 | > 27 |
| Min. Temperature (°C) | 12 | 10 | < 8 |
| Salinity (average)(L') | 25 - 37 | 15 - 25 | < 15 |
| Salinity fluctuations (L') | < 5 | 5 - 10 | > 10 |
| Dissolved oxygen (%) | 100 | 70 - 100 | < 70 |
| Turbidity/Suspended solids | Low | Moderate | High |
| Sediment type | Sand or gravel | Mixture | Mud |
| Water classification | Oligotrophic | Mesotrophic | Eutrophic |
| Fouling | Low | Moderate | High |
| Predators | No | Few | Abundant |

Table 2
Variables used for site selection of mussel mitigation culture in Denmark

| Criteria | Danish thresholds |
|---|---|
| *Physical* | |
| Bathymetry | Minimum 4–5 m |
| Wave action | Coastal areas with a minimum fetch |
| Residence time | Coastal areas with eutrophication symptoms usually have long residence time |
| *Water quality* | |
| Temperature | 0 < temperature < 25 °C, ice coverage do not stop mussel production |
| Salinity | >13 PSU |
| Chlorophyll *a* | >3 µg $L^{-1}$ all year long for eutrophic areas |
| Dissolved oxygen | Short long-lines above zone of anoxic conditions |
| *Species* | |
| Natural recruitment | Mussel spatfall naturally occurring in the area |
| Predation/fouling | Low level of predation and fouling |
| *Socio-economic* | |
| Marine spatial planning | Conflict of interest with other activities; Social acceptance |
| Harbour/distribution | Logistics and facilities close to the mussel farm for product distribution |
| Use of the raw material | Defined end product food, feed or fertilizer processing close to the farm |

# Culture modelling

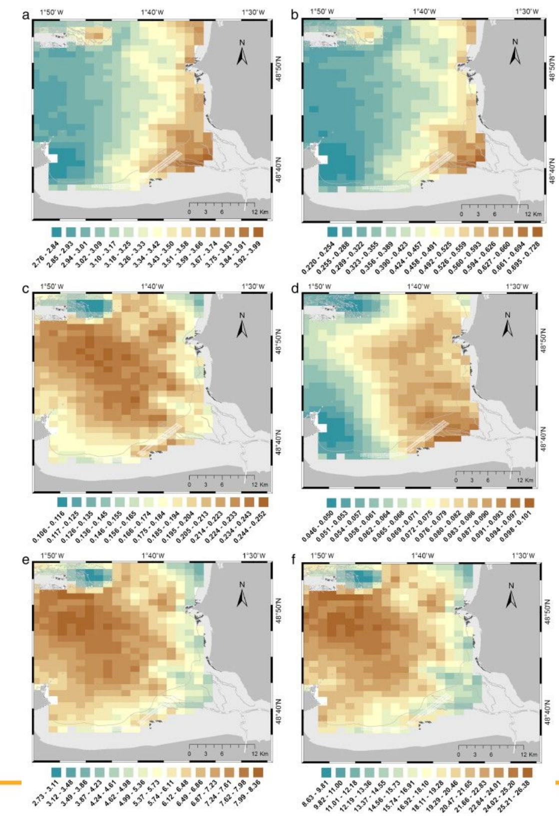
(...) Phytoplankton chlorophyll provides the main input to a bioenergetic model of mussel growth, using the '**dynamic energy budget**' approach.




https://www.nioz.nl/en/expertise/wadden-delta-centre/data-tools/modelling/dynamic-energy-budget

Fig. 7. Maps of the final averaged shell length (cm; a) and dry flesh mass (g; b) simulated by the DEB model. Standard deviations (SD) and coefficient of variation (CV) are given respectively for shell length (SD: c; CV: e) and dry flesh mass (SD: d; CV: f).

Thomas et al., 2011
https://doi.org/10.1016/j.seares.2011.04.015



- Remote Sensing Applications in Marine Aquaculture
Grant et al., 2009

IOCCG Rep.8, 2009

## HABs - Harmful Algae Blooms

(...) Ideally, one would also like to determine whether or not the phytoplankton are harmful. This would only be possible by remote sensing if the harmful algae had some spectral optical characteristic that could be used to distinguish them from other types of phytoplankton. Only a small number of harmful or nuisance algal blooms, (...) have such characteristics that could be exploited in remote sensing.

In the absence of such traits, the primary usefulness of remote sensing in this context is as a tool for systematic and sustained observations of algal dynamics in the vicinity of aquaculture sites. When remote sensing indicates rapid changes in algal biomass, this could trigger a more detailed in situ observation to classify the types of algae involved, and determine potential harm, if any, to aquaculture.

## HABs - Harmful Algae Blooms - Pacific example

(...) Imagery from the MERIS and MODIS-Aqua sensors revealed the extent of the toxic Gymnodinium chlorophorum blooms that occurred in southern Chile in 2004 and 2005

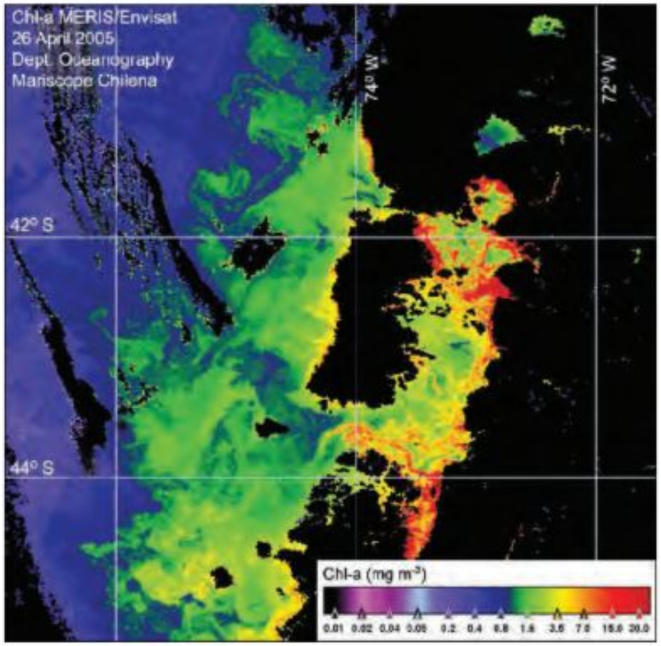


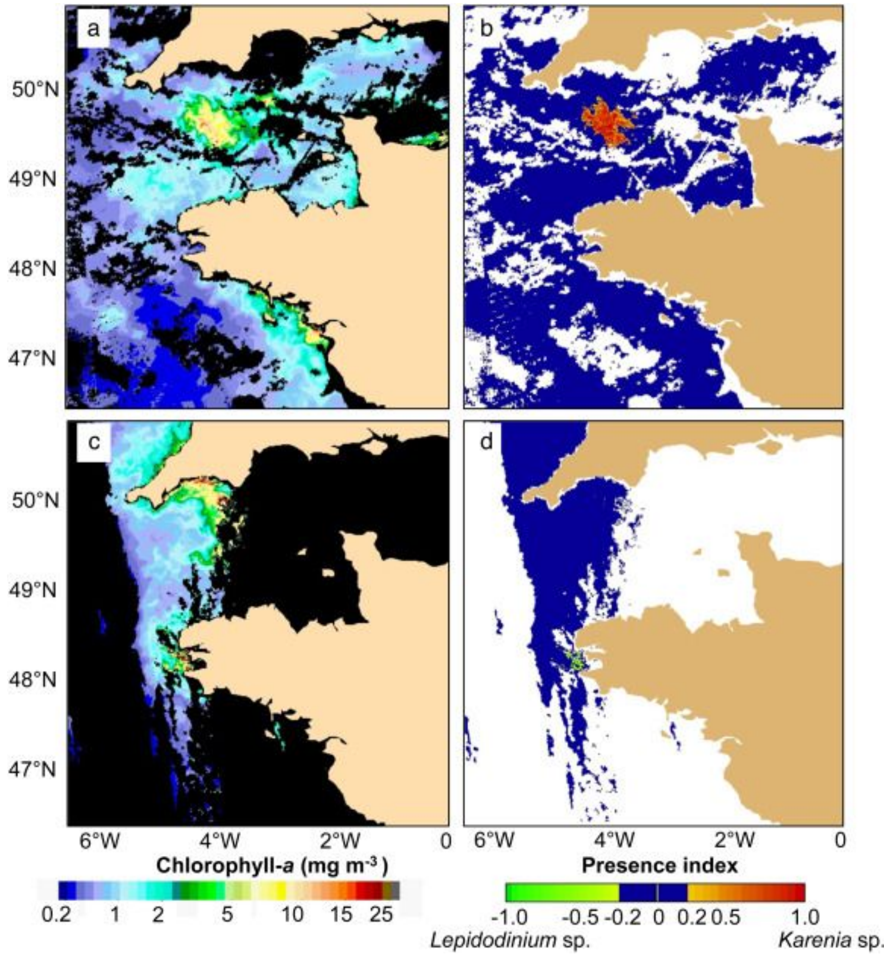

**Figure 6.5** An extensive bloom of the dinoflagellate *Gymnodinium chlorophorum* in southern Chile, captured by the MERIS sensor on 26 April, 2005. Image data provided by the European Space Agency under the Category 1 Project 1336.

- Distribution and dynamics of two species of Dinophyceae producing high biomass blooms over the French Atlantic Shelf

Sourisseau et al., 2016

# HABs - Harmful Algae Blooms - Atlantic example

Fig. 4. Chlorophyll *a* (estimated with the algorithm called OC-5, Gohin et al., 2002) and presence index maps for two events used for defining the average optical signature of the two species. *K. mikimotoi* was in summer 2003 (a and b, 2003/06/23) and *L. chlorophorum* in 2006 (c and d, 2006/09/16). (a) Chlorophyll-*a* on *K. mimimotoi* event; (b) Fuzzy Index (red) clearly identifying *K. mikimotoi* in stratified waters of the western English Channel; (c) Chlorophyll-*a* on *L. chlorophorum* event; (d) Fuzzy Index (green) identifying *L. chlorophorum* off western Brittany. Blue color is used when abs (index) is lower than 0.2.



# EO for Fisheries and Aquaculture

| Facts | Gaps |
|---|---|
| RS provides data at the required resolution in space and time to elucidate the links between the physical and biological aspects | Sparse (in situ) availability of information on the state of the wider ecosystem structure and processes |
| RS allows the quantification of parameters relevant in the identification of areas suitable for aquaculture | Accuracy of RS estimates is poor for some coastal shallow areas |
| RS provides valuable information to detect possible toxic algal blooms and its drift | Actual toxicity can only be confirmed from in situ sampling. Only high biomass HABs can be detected |

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# THANK YOU!

# Global marine primary production constrains fisheries catches
[Chassot et al., 2010]

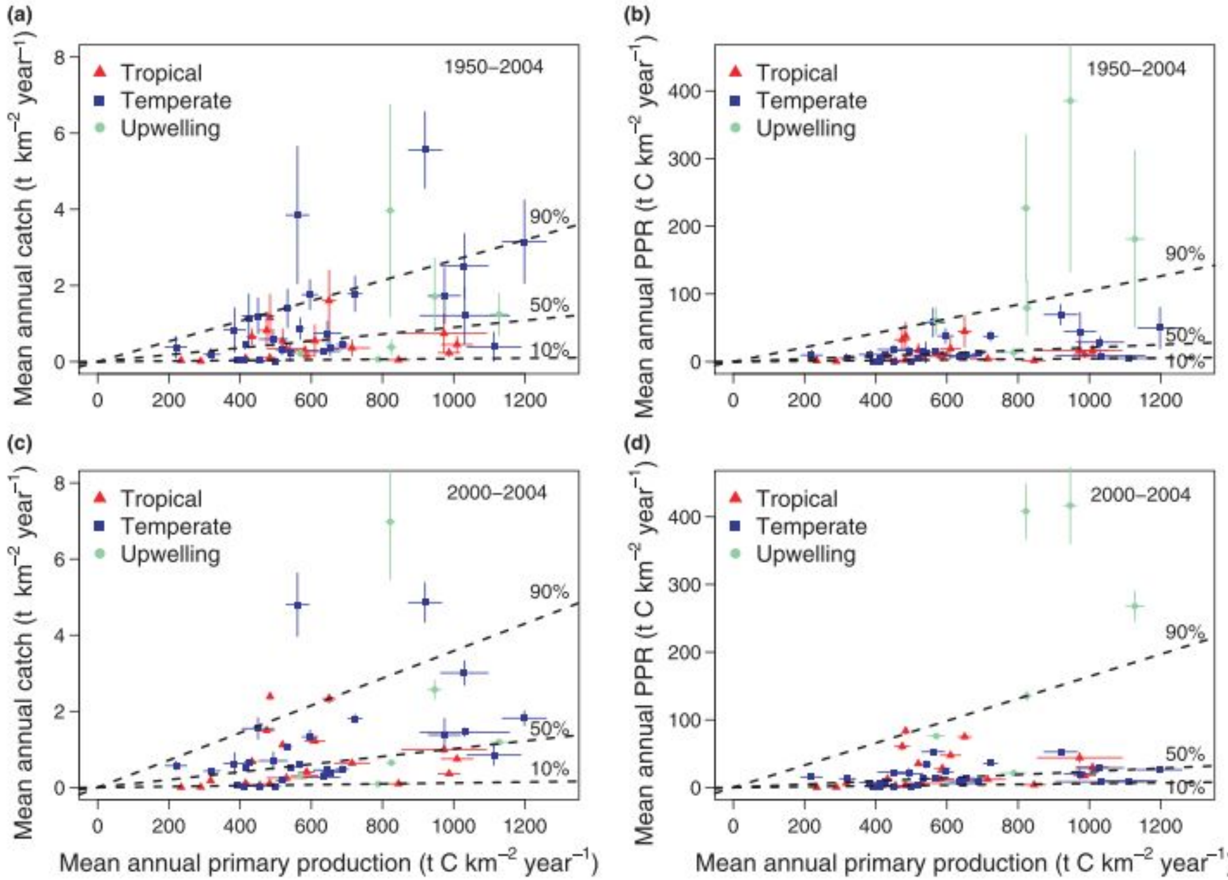
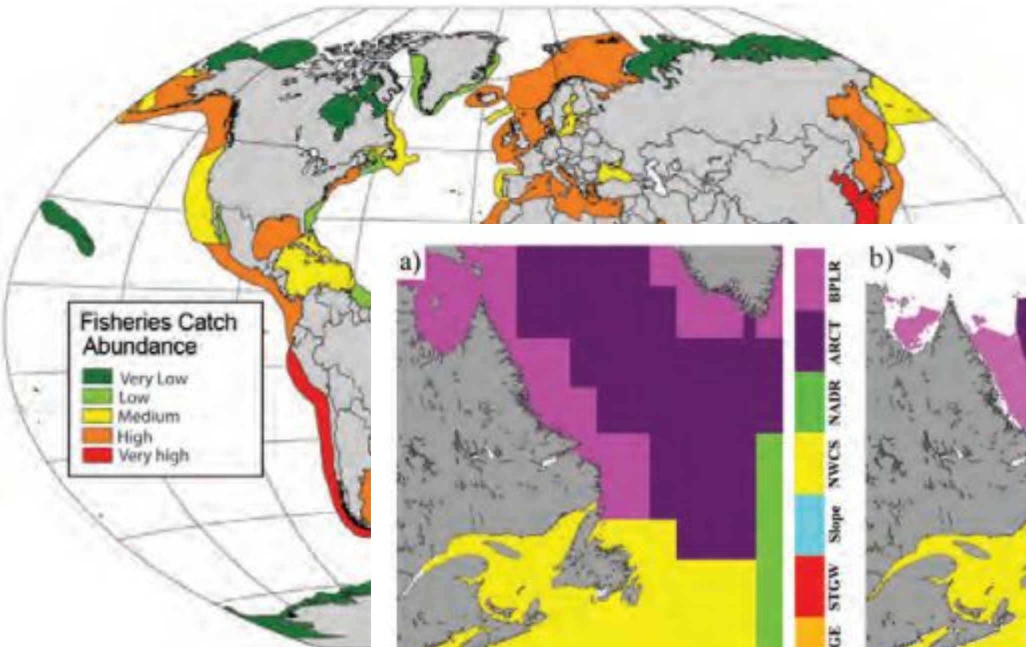



**Figure 1** Global marine primary production (PP) and fisheries production expressed in (a,c) catch (t km$^{-2}$ year$^{-1}$) and (b,d) primary production required (PPR) to sustain catches (in t C km$^{-2}$ year$^{-1}$) over the long-term period (1950–2004) and recent period (2000–2004). Solid lines indicate quantile regressions models with quantile = 10%, 50%, and 90%.

- Remote Sensing Applications to Marine Resource Management

Wilson et al., 2009



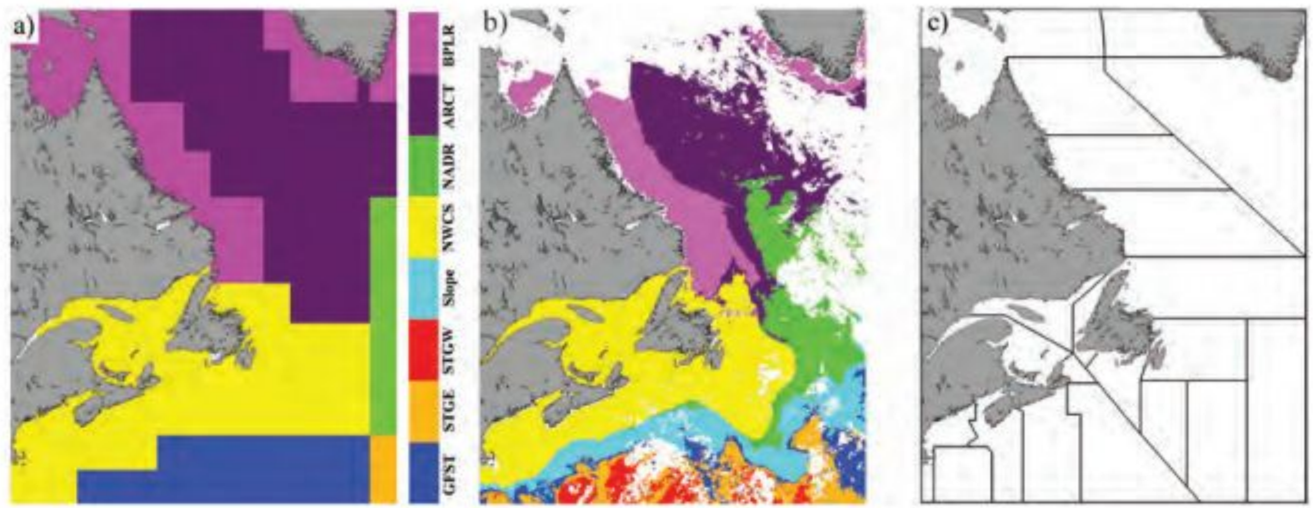




**Figure 4.2** Outline of the 6
fisheries catch abundance fo
gov/).

**Figure 4.3** Ecological partitions of the northwest Atlantic Ocean, (a) static partition according to Longhurst (1998); (b) dynamic partition according to Devred *et al.* (2007), for 16 to 31 October 2001; (c) static partition of the Northwest Fisheries Organisation (see Halliday and Pinhorn, 1990). Figure modified from Platt and Sathyendranath (2008).

- Remote Sensing Applications to Marine Resource Management

Wilson et al., 2009

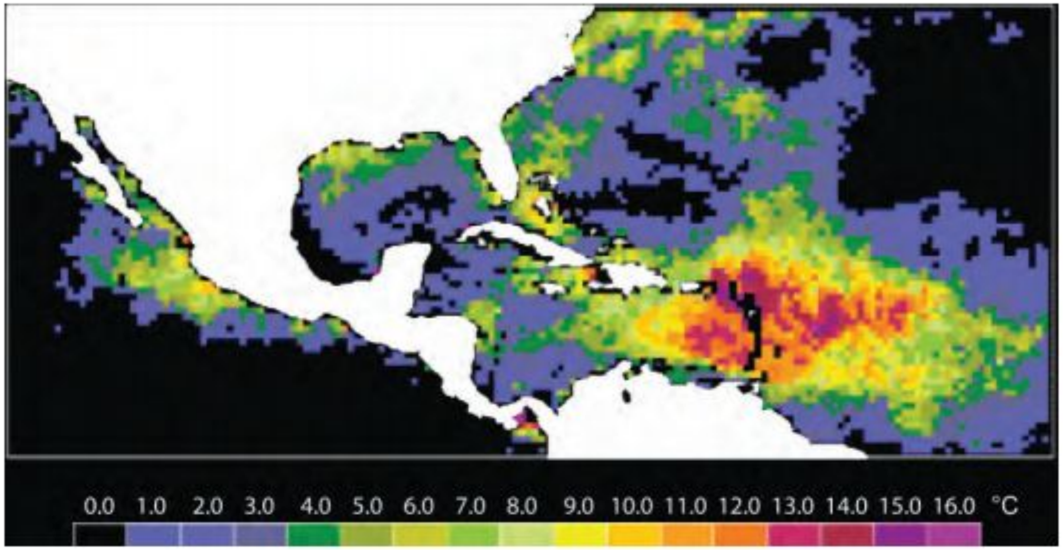



**Figure 4.4** Map of an unusual heating in the Caribbean for the summer of 2005 when a massive bleaching event occurred. Results are presented as anomalies of sea-surface temperature (SST) above the expected summer-time maximum, over a one week period, expressed as 'Degree Heating Weeks' (DHWs). One DHW is equivalent to one week of SST greater than expected summertime maximum by 1°C. DHWs greater than 10 indicate the existence of high and persistent SST, with a high probability that coral reefs may be undergoing severe bleaching, and possible mortality.

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- Remote Sensing Applications to Marine Resource Management

Wilson et al., 2009

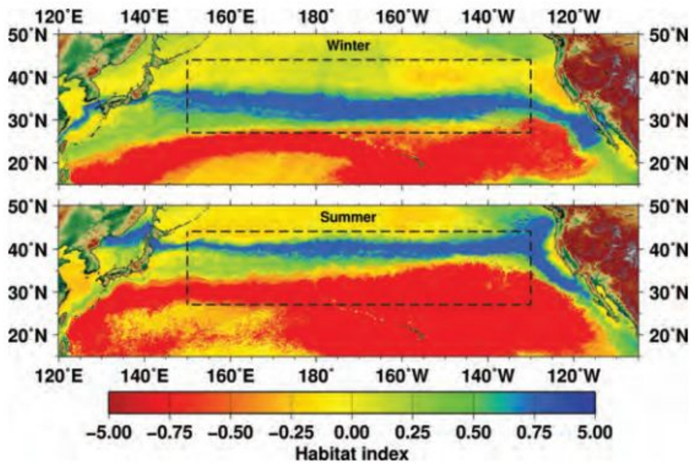


**Figure 4.6** Seasonal climatological habitat map for pelagic loggerhead sea turtles in the north Pacific based on Pathfinder SST, SeaWiFS chlorophyll and 3 magnetic variables. Blue areas represent a high probability of finding loggerhead sea turtles. Modified from Kobayashi *et al.* (2008).

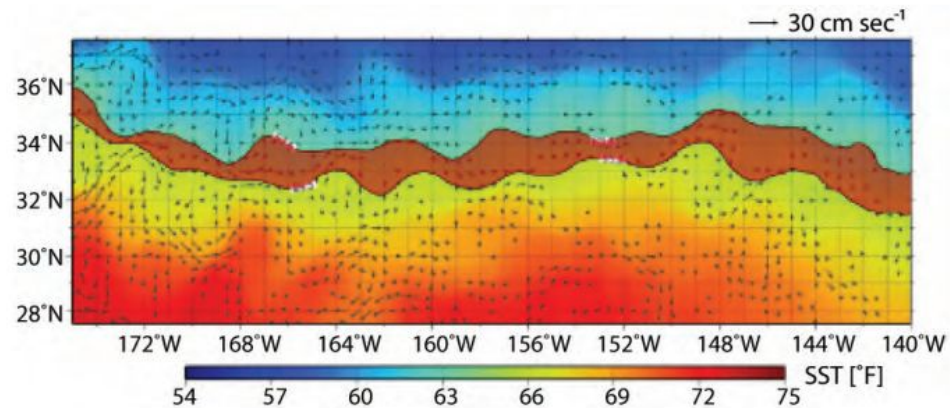


**Figure 4.7** The TurtleWatch product. SST represented as a colour background, geostrophic currents estimated from satellite altimetry shown as black arrows, and the zone with the highest probability of bycatch of loggerhead sea turtles is shown in brown (defined as the area between 63.5°F and 65.5°F). Longline fisheries should be restricted from these areas to lower bycatch rates.