

Stichting DLO Centre for Fisheries Research (CVO)

KBWOT 2011: Maintaining the quality of WOT shellfish stock assessments

Karin Troost, Marnix Poelman, Johan Craeymeersch & Jeroen Jansen

CVO report: 12.004



Commissioned by:
EL&I Directie Kennis
Postbus 20401
2500 EK DEN HAAG

Project number: 4301900336
BAS code: KB-14-012-008

Publication date: March 12, 2012

Stichting DLO
Centre for Fisheries Research (CVO)
P.O. Box 68
1970 AB IJmuiden
Phone. +31 (0)317-487418
Fax. +31 (0)317-487326

Visitor address:
Haringkade 1
1976 CP IJmuiden

© 2011 CVO

De Stichting DLO- Centre for Fisheries Research is registered in the Chamber of commerce in Gelderland nr. 09098104, VAT nr. NL 8089.32.184.B01
CVO rapport UK V4.2

This report was prepared at the request of the client above and is his property. No part of this report may appear and / or published, photocopied or otherwise used without the written consent of the client.

Table of Contents

Table of Contents.....	3
Summary	4
1 Introduction.....	6
2 Workshop 1: stock assessment techniques	7
2.1 The workshop: Aim and set-up	7
2.2 Summary of Session 1: Traditional survey techniques and sampling strategy	8
2.2.1 Summary of the presentations.....	8
2.2.2 Summary of the discussion session	10
2.3 Summary of session 2: new techniques	11
2.3.1 Summary of the presentations.....	11
2.3.2 Summary of the discussion session	12
2.4 Summary of session 3: addressing policy questions adequately	13
2.4.1 Summary of the presentations.....	13
2.4.2 Summary of the discussion session	13
3 Workshop 2: taxonomy and ageing of bivalve shellfish	14
3.1 Introduction	14
3.2 The workshop.....	14
4 Conclusions.....	16
4.1 Conclusions of Workshop 1: Stock assessment techniques	16
4.2 Conclusions of Workshop 2: taxonomy and ageing	16
5 Recommendations for the WOT shellfish surveys	17
5.1 Stock assessment techniques	17
5.1.1 Sampling grid and confidence estimates.....	17
5.1.2 New techniques	17
5.2 Skills in identification and ageing	17
Signature.....	19
Appendix (all presentations).....	20

Summary

The Centre for Fisheries Research (CVO) of Wageningen-UR carries out statutory research tasks (“wettelijke onderzoekstaken”, WOT) for the Ministry of Economic Affairs, Agriculture and Innovation (EL&I). These research tasks include stock assessments of exploited fish and shellfish species that are carried out by IMARES. In 2011, a project with the aim to improve the quality of the WOT shellfish surveys in Dutch coastal waters was funded by the KBWOT Fisheries programme. Results, conclusions, and recommendations of this project are presented in this report.

To guarantee the quality of the shellfish surveys, the following goals are set: A) a structure, according to which the quality of the data can be guaranteed, needs to be set-up, B) methods used need to be compared to methods used abroad, and C) the availability and applicability of new methods that may enhance efficiency need to be explored.

In order to meet these goals, an innovative approach was taken to apply the KBWOT Fisheries funds: through sharing knowledge and building networks through the organization of two workshops:

1. A workshop with international experts in the field of shellfish stock assessments and acoustic techniques (November 3 – 4, 2011), with the aim of comparing our techniques with those used abroad, to set up an international network for knowledge exchange and cooperation, and to explore new techniques that may increase efficiency and accuracy. This addresses goals B-C in the above paragraph;
2. A workshop with national experts in the field of taxonomy of benthic fauna, in particular bivalve shellfish (November 21, 2011). This workshop also included ageing of cockles *Cerastoderma edule*. The aim was to maintain skills in identifying bivalve shellfish and other commonly encountered species, and in ageing cockles. This addresses goal A in the above paragraph.

Both workshops were carried out successfully in November 2011. The main conclusions were:

1. the workshops have brought together experts in the field of stock assessment techniques, novel techniques for habitat mapping (acoustic techniques, remote sensing), and bivalve taxonomy;
2. the workshops therefore resulted in the set-up of (international) networks which holds a promise for further collaboration and sharing of knowledge and skills;
3. the initial goals of the workshops have all been met and therefore the project has contributed significantly to maintaining the quality of the WOT shellfish surveys, thereby offering scope for improvements in accuracy and efficiency.

Nederlandse samenvatting (Dutch summary)

Het Centrum voor Visserij Onderzoek (CVO) van Wageningen-UR is verantwoordelijk voor de wettelijke onderzoekstaken (WOT) voor het Ministerie van Economische Zaken, Landbouw en Innovatie (ELI). Deze onderzoekstaken betreffen onder andere bestandsschattingen van beviste vissoorten en schelpdiersoorten die worden uitgevoerd door IMARES. In 2011 is binnen KBWOT Visserij een project uitgevoerd met het doel om de kwaliteit van de schelpdierbestandsschattingen in de Nederlandse kustwateren te verbeteren. Resultaten, conclusies en aanbevelingen worden hier gerapporteerd.

Om de kwaliteit van de schelpdiersurveys te waarborgen en waar mogelijk te verbeteren zijn de volgende doelen gesteld: A) er moet een structuur worden opgezet die de kwaliteit van de surveys kan waarborgen; B) gebruikte onderzoeksmethoden moeten worden gespiegeld aan die gebruikt in andere landen en gebieden; C) onderzocht moet worden tot in hoeverre nieuwe technieken beschikbaar en toepasbaar zijn, en of deze de efficiëntie en accuratesse van de surveys kunnen verbeteren. Om deze doelen te bereiken is binnen KBWOT Visserij financiering aangevraagd en verkregen voor het organiseren van twee workshops. Dit is een innovatieve benadering voor de besteding van KBWOT budget. De twee workshops hielden het volgende in:

1. Een workshop met internationale experts op het gebied van schelpdierbestandsschattingen en nieuwe methoden zoals akoestische technieken en remote sensing (3-4 November). Het doel was om 1) onze technieken met die gebruikt in het buitenland te vergelijken, 2) een internationaal expertnetwerk op te zetten voor het delen van kennis en samenwerking, en 3) de toepasbaarheid van nieuwe technieken te onderzoeken. De workshop draagt daarmee bij aan boven gestelde doelen B-C;
2. Een workshop met experts op het gebied van taxonomie en leeftijdsherkenning in schelpdieren en ander macrobenthos (21 November). Het doel was om de kennis en bedrevenheid in het herkennen van soorten en het onderscheiden van leeftijden bij de kokkel *Cerastoderma edule* te handhaven en bij de nieuwere medewerkers te verbeteren. Het organiseren van een dergelijke workshop draagt bij aan bovengenoemd doel A, met name als de workshop periodiek wordt herhaald.

Beide surveys zijn in November 2011 gehouden en met succes afgerond. De belangrijkste conclusies waren dat: 1) de workshop experts hebben samengebracht op het gebied van bestandsschattingen, nieuwe technieken voor habitat kartering, en taxonomie van tweekleppige schelpdieren; 2) de workshops daardoor hebben geresulteerd in (internationale) netwerken voor het delen van kennis en eventuele verdere samenwerking; 3) alle gestelde doelen voor de workshops zijn behaald en het project daardoor significant bijdraagt aan het behouden en waarborgen van de kwaliteit van de schelpdiersurveys waarbij mogelijkheden voor verdere verbetering zijn gesignaleerd.

1 Introduction

The Centre for Fisheries Research (CVO) of Wageningen-UR carries out statutory research tasks (“wettelijke onderzoekstaken”, WOT) for the Ministry of Economic Affairs, Agriculture and Innovation (EL&I). These research tasks include stock assessments of exploited fish and shellfish species that are carried out by IMARES. In 2011 a project with the aim to improve the quality of the WOT shellfish surveys in Dutch coastal waters was funded by the KBWOT Fisheries programme. Results, conclusions, and recommendations are presented in this report.

The KBWOT Fisheries programme has an active policy of underpinning the key-expertise required to carry out the statutory tasks (WOT), and of encouraging the further development the expertise needed to complete those tasks. The programme operates through long term projects (multiannual) and annual projects in response to scientific and societal needs. It conforms to the wider Wageningen-UR strategic approach of Kennisbasis (KB, “Knowledge Basis”) research being innovative, supportive and exploratory. Innovative and exploratory research is encouraged into integrated assessments of the ecosystem, impact of fishing, multispecies and maximum sustainable yield considerations in fisheries management whilst supportive research is maintained into acoustic survey techniques, biological parameters and ageing of fish and shellfish. The programme is administered by a panel of marine scientists, who review the programme each year, meet with civil servants from the Ministry of Economic Affairs, Agriculture and Innovation (EL&I) and circulate an annual report. This programme is part of the larger KB programme carried out by Wageningen UR and has been developed in consultation with the Ministry of EL&I. The programme is mostly populated with projects resulting from an annual call for proposals. The core principles of the programme are maintaining expertise whilst being forward looking, ensuring value for money and strong collaboration with client ministries.

Themes addressed in 2011 were: 1. Ecosystem Approach, 2. Maximum Sustainable Yield targets for North Sea flatfish, 3. Maintaining Quality, 4. Development of fish objectives for the Marine Strategy Framework Directive, 5. International Exchange. This report shows the results of a granted proposal addressing Theme 3 “Maintaining Quality”. The project “Quality of Shellfish Surveys” was granted and carried out in 2011 with the aim to improve the quality of the WOT shellfish surveys carried out by IMARES (since the early 1990s). To guarantee the reliability of collected data, A) a structure, according to which the quality of the data can be guaranteed, needs to be set-up, B) methods used need to be compared to methods used abroad, and C) the availability and applicability of new methods that may enhance efficiency need to be explored. In order to meet these goals, an innovative approach was taken to apply the KBWOT Fisheries funds: through sharing knowledge and building networks through the organization of two workshops:

1. A workshop with international experts in the field of shellfish stock assessments and acoustic techniques (November 3 – 4, 2011), with the aim of comparing our techniques with those used abroad, to set up in international network for knowledge exchange and cooperation, and to explore new techniques that may increase efficiency and accuracy. This addresses goals B-C in the above paragraph;
2. A workshop with national experts in the field of taxonomy of benthic fauna, in particular bivalve shellfish (November 21, 2011). This workshop also included ageing of cockles *Cerastoderma edule*. The aim was to maintain skills in identifying bivalve shellfish and other commonly encountered species, and in ageing cockles. This addresses goal A in the above paragraph.

2 Workshop 1: stock assessment techniques

2.1 The workshop: Aim and set-up

This workshop brought together international experts in the field of shellfish stock assessment (Figure 1). The aim was to investigate whether improvements in our techniques are necessary and feasible, and how comparable our methods are to those used abroad. Results aimed for were: a higher degree of efficiency of our surveys, a better quality and therefore enhanced reliability of our data, and a better connection to international developments in this area of expertise. An enhanced quality of data allows for earlier detection of changes in stock sizes and a more reliable link to possible causes of the observed changes. In the light of an increased efficiency, the benefits and necessities of new methods such as sonar and remote sensing were also discussed.



Figure 1. Participants of the international workshop on stock assessment techniques, November 3-4 2011 in Yerseke.

With the workshop, a network is set up that may result in future collaborations and publications, and within which IMARES may be consulted as an international expert and involved in new developments.

The aim of the workshop was to:

- 1- Compare methods used in different countries / coastal systems;
- 2- Explore the potential of new techniques (e.g. acoustic techniques, remote sensing);
- 3- Identify points for improvements in accuracy and efficiency;
- 4- Set-up an international network of people involved in shellfish stock assessments.

The workshop consisted of three sessions:

- 1- Traditional survey techniques and sampling strategy (November 3rd);
- 2- New techniques (November 4th);
- 3- Addressing policy questions (November 4th)

In each session, a series of lectures was given, followed by a discussion. The sessions and discussions were chaired by Karin Troost and Marnix Poelman. The list of participants and presentations given are included in the appendix of this document.

2.2 Summary of Session 1: Traditional survey techniques and sampling strategy

2.2.1 Summary of the presentations

Marnix van Stralen presented techniques used by IMARES and MarinX in surveys in Dutch coastal waters, and the historical development of sampling strategies and methods used. In the Dutch Wadden Sea, the following commercially exploited species are monitored: cockle (*Cerastoderma edule*), mussel (*Mytilus edulis*), and Pacific oyster (*Crassostrea gigas*). Marnix focussed on sampling methods used in the intertidal: a stratified fixed sampling grid (along transects), a modified suction dredge, a trawled dredge, and a special dredge (scoop; picture on title page) for cockles that is operated by hand from a small boat. He identified several challenges in these surveys (high variability in space and time, limited time between survey and fisheries, limited budgets), and posed the following discussion points:

- Stratified random versus grid based surveys: what is best?
- Given a limited budget: what is the trade-off between the number of stations and effort per station?

James Strong presented the different methods used for stock assessments of seed mussels around Ireland by three different agencies: Agri-Food and Biosciences Institute, Northern Ireland (United Kingdom), Loughs Agency (NI/ROI cross boarder organisation), and Bord Iascaigh Mhara (Republic of Ireland). These different agencies use different strategies and sampling gear (different mussel dredges). Usually, a one-step approach is used. James recommends a two-step approach in which as a first step data on distributions are collected using acoustic techniques or information from the industry. Furthermore, communication of the results requires standardisation. Communication of techniques used to fishermen requires a simple, transparent approach that is easily understandable.

Identified discussion points:

- With some mussel dredges only the extractable stock is determined, instead of the total stock. Which is preferable? Understanding the relationship between both seems important.
- Would it be better to use the same dredge for all surveys? How to determine efficiencies?
- What extra environmental parameters need to be determined in order to better understand settlement processes?

Ron Jessop presented an overview of techniques used in the Wash estuary, in England. Here, stock assessments are carried out for cockles (*C. edule*) and mussels (*M. edulis*). Additional habitat mapping includes sediment data and data on invertebrates (*Macoma*, *Lanice*, *Arenicola*). Cockles are sampled using a fixed grid. Contours of intertidal mussel beds are mapped using GPS. For estimating cover, instead of using the "foot on mussels" or "boot" method, they now sample the mussels using a ring while walking along transects through the mussel bed. Sublittoral mussel beds are localized using Roxann AGDS and dredges. Additionally, studies are performed on cockle discard mortality, impacts of "prop washing" cockle fisheries, and egg scrubbing in lobsters.

Roger Mann gave two presentations on this first day. In the first one he presented an overview of 15 years of oyster assessments in the Virginia portion of the Chesapeake Bay. He stated that the "purpose" is the most important issue in stock assessments. Biological studies have a completely different approach

than large scale system objectives. In the Chesapeake Bay oyster stock assessments, a random stratified grid (in 23 reef systems) is based on historical data (maps by Baylor) and historical fishery boundaries. Nowadays a hydraulic patent tong is used for sampling, but many calibrations between different gear types were assessed. Sampling is continued until the standard error is sufficiently minimal. For quantitative assessments, an oyster dredge was deemed unsuitable. After sampling, collected data on population structure allow for forward estimations of age structure and optional quota with year specific disease impacts. Roger stressed that such calculations must be tools that can be understood by the regulators and the end users. Otherwise they will not be accepted. The following discussion points were identified:

- Choices for stratification and post-stratification depend on the question asked (and available budget)
- Trade-off between survey redesign and continuation of a long-term dataset
- Compromise of limited funds and a fixed survey period
- Mapping species or habitats?

Alexandra Markert presented techniques used for stock assessments of Pacific oysters (*Crassostrea gigas*) in the Central Wadden Sea (Lower Saxony). Methods used for determining the contour of intertidal oyster beds is the standard method used throughout the Wadden Sea (TMAP) for mapping mussel beds (*M. edulis*). Contours are mapped using a GPS. To determine the coverage, the "boot" method is used. The same transects are walked every year (and "mussels under foot" counted). A total of 15 mussel/oyster beds is visited every year, and per bed 12 samples are taken with a 1/16 m² quadrant for further analysis. From these samples, not only data on biomass and length frequencies of *M. edulis* and *C. gigas* are collected, but also data on the occurrence of associated fauna. Alexandra furthermore provided information on the logistic effort made for this survey every year.

Heike Büttger presented an overview of stock assessments of mussels (*M. edulis*) and Pacific oysters (*C. gigas*) in the Eastern part of the Wadden Sea (Schleswig Holstein). For mapping contours of intertidal beds, the same techniques are used as in the Western Wadden Sea (Netherlands) and Central Wadden Sea (Lower Saxony). These techniques are standardised according to TMAP (Trilateral Mapping and Assessment Program) protocol. For an estimate of cover, the "boot" method is used. Unlike in Lower Saxony, here transects are random and differ from year to year. Additional information on mussel/oyster bed area is obtained from aerial photographs, although this method is not always 100% reliable, depending on time of the year and type of substrate. Ground truthing is therefore essential. A clear distinction is made between mussel beds and oyster beds, depending on dominance in biomass. For mussel stock assessments, a ring with a diameter of 15 cm is used for sampling. For oysters, a 1/16 m² quadrant is used. To assess sub tidal stocks a special dredge is used (width 70 cm). Effort is concentrated in areas with historic presence of mussel beds.

Roger Mann presented on the biology of reef forming species and what we should measure in addition to the typical density, length and weight data, in his second presentation. Roger showed that mapping the presence of shellfish habitat (or 'carbonate' beds) may be very important in predicting future stocks and their localities. He also showed how the destruction of these 'carbonate beds' (especially relevant for *C. virginica* in the Chesapeake Bay), may have a large impact on opportunities for development and restoration of stocks. He hypothesized that growth of settling and recruiting spat and juveniles may be limited in carbonate availability in a suitable chemical environment.

2.2.2 Summary of the discussion session

Calibration of sampling devices, and comparisons of efficiency

Dredge efficiency was identified as possibly one of the largest sources of error. A reference was made to Per Dolmer who has written about the efficiency of mussel dredges (P. Dolmer, P.S. Kristensen and E. Hoffmann, Dredging of blue mussels (*Mytilus edulis* L.) in a Danish sound: stock sizes and fishery-effects on mussel population dynamic. *Fish. Res.*, 40 (1999), pp. 73–80). It was agreed that a sensitivity analysis is important, and one should at least have an indication of the efficiency of the sampling gear. A possible method would be a depletion experiment: to sample the same track over and over until everything is fished. However, in most cases it is not feasible to fish the exact same track. Additionally, an example was given (by Johan Craeymeersch) of an experiment in which a ship trawled the same track several times (Reiss, H., Kröncke, I., Ehrlich, S., 2006. Estimating the catching efficiency of a 2-m beam trawl for sampling epifauna by removal experiments. *ICES Journal of Marine Science* 63, 1453-1464). Catches did not decrease per consecutive trawl, and for some species even an increase was observed. This could be explained by the fact that the first dredge did not catch some species but stimulated them out of the sediment where they were caught by the following dredge.

The percentage of the time that a dredge keeps contact with the bottom is something that can be monitored using aquadopps or (towed) camera systems. Johan Craeymeersch has experience with the use of aquadopps on a trawled dredge. In his experience the dredge may come out of the bottom 20% of the time. This depends on the characteristics of the substrate. He also used an altimeter, but measurements were confused because of resuspension of sediments. There are also devices that register tilt and pressure (experience Dvora Hart). Marnix van Stralen stressed that measured efficiency may be dependent on the time of year, since mussels come out of the sediments in early spring. This was confirmed by Ron Jessop. The phenomenon of mussels crawling into the sediment during winter may have led to an underestimation of the mussel stock in a particular year. A good way of testing the efficiency is to sample at high tide in the intertidal and visit the sampling area during low tide.

A common problem of dredges and grabs is "filling up": when did the device fill up and how much of the catch was lost (grab with open top) or missed (dredge) because of that? Filling up was identified as being a greater problem in sampling with dredges. Because of the risk of filling up, mussels in the Wash are sampled using a (Day) grab instead of a dredge (Ron Jessop). One should determine the aim of the study(results) prior to using this method.

For validation, in some cases fished tonnages may be used. This is the case in the seas around Ireland, where all mussel seed is completely fished away every year (James Strong). In the Wash, an attempt is also made to use tonnages for validation, and post-fisheries monitoring is carried out. After the fisheries about 70% of a bed may be left (Ron Jessop). A plea was made for using more than one method. As an example, Sabellaria reefs in the Wash are first localised using RoxAnn. RoxAnn results are used to stratify the grabs, and additional information is gained from and underwater camera. Cameras are also used around Ireland (Strong), to assess the patchiness in mussel beds.

Sampling design: stratified random or grid-based?

In general, stratification is preferred and should increase efficiency and accuracy. It is, however, an essential prerequisite to use a correct information basis. This was the outcome of a student project at VIMS (information provided by Dvora Hart). The main advantage of sampling randomly is that, over time, the entire area will be sampled. The main advantage of sampling according to a fixed grid is that temporal trends are easier to detect. This may be dangerous, as was shown in an example by Dvora Hart considering scallop monitoring: grid points with high scallop densities were heavily fished. In surveys in

the following years the stock was probably underestimated because these grid points had relatively low densities left in comparison to the surrounding area. Such a problem may be solved by using a fixed grid in which the sampled points are rotated from year to year. A fixed grid gets riskier with lower stocks present. This also hampers the estimation of confidence intervals using bootstrapping techniques. If the amount of sampling points is too low, randomization from year to year should be accounted for. Random sampling also have large disadvantages: spatial changes from year to year may be difficult to detect, and it is impossible to follow year classes. For spatial statistics, a fixed grid may be better but the distance between sampling points is crucial. In conclusion, whether to use a random strategy or a fixed one depends mainly on the research question. For random sampling it is easier to determine a variance and confidence limits from the obtained data. For fixed grids, the error may be overestimated. But: better overestimated than underestimated.

Single-species vs. multi-species monitoring

If the aim is to assess the stock of a particular species, monitoring should be ideally focussed on this species alone. Focussing a survey on several shellfish species may require to make compromises in the survey design and result in a reduced accuracy for all species. Furthermore, taking into account associated fauna as well may give much more information on variations in time and space. For instance, there is a negative relationship between starfish and scallops. It was stressed, however, that the methods should stay right for the initial purpose of the survey. In the end, the number of stations sampled is a matter of research question and the available budget and time. Ron Jessop and colleagues have been experimenting with the number of samples per station, but haven't analysed the results yet.

2.3 Summary of session 2: new techniques

2.3.1 Summary of the presentations

Johan Craeymeersch started the session with an introduction to the topic of new techniques, and their potential purpose as a basis for stratification. He presented experiences with side scan sonar (which gave a lot of noise and was more clear for epifauna than endofauna), and an echosounder. The echosounder trials still need to be repeated in the intertidal where ground-truthing may take place during low tide. Johan stressed that a lot of experience in processing sonar results to get rid of the noise. In response to a question by Roger Mann about depth effects on noise, several persons responded that side scan sonar (and more specifically RoxAnn) give no problems in shallow water. Waters more shallow than 3.6 meters do become a problem according to Ron Jessop. In the Wadden Sea, side scan sonar is often used for detection of mussel beds in waters up to 5 meters deep (Cor Smit).

James Strong showed how optimum allocation analysis (OAA) is applied in mussel stock assessments around Ireland, and how this helps to optimize the compromise between effort and accuracy. OAA helps to define/distribute ground-truthing samples which results in an increased efficiency at a minimised effort. It may be used to acquire maximum precision at a certain cost, or to minimise the cost at a certain precision. The method is commonly used in finfish fishery biology. A macro, manual and report can be found on the website (<http://www.afbini.gov.uk/index/services/facilities/coastal-science-seabed-mapping.htm>).

Vera van Lancker presented her work on exploring the use of multibeam to discern bottom types, and possibly dense shellfish beds, in the North Sea coastal areas of Belgium and the Netherlands. A large part of the experimental sampling has been focussed on the "Vlakte van de Raan" area, where there have been dumpings of dredges sediments. Ecosystem engineers that occur in high densities can be

discerned because they change the structure (profile) of the bottom. Ground-truthing is essential in this project, and earlier attempts did not give good results because the grid used for ground-truthing was too coarse. Bottom trawling by fishery vessel gave a very strong signal because trawling tracks have relatively steep slopes. For validation, Vera recommended to use existing information as much as possible (e.g. bathymetry), and to combine different surveys as close as possible. It is possible to distinguish biological from physical structure, but there is still a lot of work to be done in fine-tuning. In response to questions Vera answered that the resolution of the grid cell sizes will not improve in the near future. Weather conditions in the North Sea are often too rough for these acoustic techniques, especially for side scan sonar. Data processing can be done during the survey, if the right software is available. In her case, however, the analyses needed to be done afterwards.

Jean-Yves Stanisiere showed how acoustic techniques are applied to stock assessments of Pacific oysters (*C. gigas*) in Quiberon Bay, France. He works closely together with Jean-Marie Augustin. Co-occurrence matrices are used to distinguish the different bottom types. Distinction between shellfish beds of different species (*C. gigas* and the slipper limpet *Crepidula fornicata*) is possible but difficult. Jean-Yves and colleagues are experimenting with the size of the tiles (the resolution of these matrices) required to still pick up the signal that is typical for the different bottom types. For some species, different tile sizes may be suitable than for other species. This will be tested. The angle at which the sonar is operated is also determining for the signal. Validation is done by video, which was considered to work very well. A difficulty is the occurrence of oysters in gravelly substrates. The most work is involved in cleaning the data before they can be analysed. The techniques used is available at IFREMER. Quite expensive, but once bought, instructions and a high level of assistance are given by Jean-Marie Augustin.

Narangerel Davaasuren gave a presentation about the use of remote sensing data in mapping bottom types on intertidal flats (Wadden Sea). The advantage of remote sensing data is that it is freely available. See for instance the Ocean Color Web, with a resolution of 250 x 250 m (<http://oceancolor.gsfc.nasa.gov/>). Disadvantages are the resolution in time, and many images are not usable because of high tide, clouds, etc. Also, the purpose of most satellite remote sensing images is land-based. Narangerel tested whether these images can also be used to distinguish bottom types on the tidal flats of the Wadden Sea, and more specifically mussel beds. She cooperated with Brockmann Consult in Germany. A reasonably good match was found with the occurrence of mussel beds in the Rottum area. However, mussel data and remote sensing data originated from different years. A next step would be to try and match data from the same year. There is still work to be done before this technique can be applied for the localization of mussel beds, but results up to now are promising. In the near future new Sentinel satellite images will become available. These will be free to use, more focussed on water, with a higher resolution (15 x 15 m).

Daphne van der Wal is also working on remote sensing data. She presented two posters on this subject.

2.3.2 Summary of the discussion session

Habitat mapping and new techniques

A main discussion point was: whether to use habitat mapping and modelling as a basis for stratification (to increase efficiency), or to use it for obtaining additional information. New techniques increasingly allow for gaining more and more additional knowledge, but this comes at a cost since these techniques require a lot of time for data analysis and groundtruthing. On the other hand, acquiring remote sensing images is free of costs. Groundtruthing is and remains essential. Interpretations of acoustic / remote sensing data may differ between areas. With increasing use of mapping techniques, groundtruthing is increasingly important. Habitat mapping using new techniques can be time consuming. Therefore Vera

van Lancker recommended to cooperate more, and share data more between research institutes. A good overview is needed of who is doing what.

It was agreed that habitat mapping offers a lot of opportunities. It may be used to increase efficiency and optimising stratification, but in practise it is mainly applied for addressing additional research questions. It may also aid in the protection of certain habitats, e.g. protection of Sabellaria reefs from shrimp fisheries in the Wash (example by Ron Jessop), and provision of seed mussel bed contours to fishermen to prevent them from fishing in other locations (example by James Strong). In addition, Vera van Lancker pointed out that we do not describe the abiotic environment in detail anymore, during our surveys. Instead, the use of new techniques for habitat mapping may give us insights in e.g. climate change.

2.4 Summary of session 3: addressing policy questions adequately

2.4.1 Summary of the presentations

Dvora Hart presented on the assessment of sea scallops (*Placopecten magellanicus*) in US waters, and on the development of stock size and fisheries. Dvora showed how management actions clearly resulted in allowing scallops to grow to a larger size before being harvested. In the surveys, a large dredge is used but also a video drop camera system and a Habcam towed digital camera. An overview was given of advantages and disadvantages of these techniques. For stock assessments and catch-at-size forecasting, size-based models with stochastic growth are used.

Eelke Folmer gave the last presentation of the day. He presented a spatio-temporal visualization of long term mussel bed distribution data collected the Dutch and German parts of the Wadden Sea. He showed that cross-border analyses may deliver new insights in processes related to population dynamics. Particularly, recruitment is an extremely important and variable component of the population dynamics in mussel beds. In addition, the trends in mussel bed area show large differences between blocks of adjacent tidal basins while within the blocks variation occurs in synchrony. Possible next steps in explaining observed patterns would be to combine these analyses with spatial data on biotic and abiotic factors such as predation and food resources and climatic parameters.

2.4.2 Summary of the discussion session

Dealing with growth between survey and fisheries

The question on how to deal with growth of the shellfish in the time between survey and fisheries was posed by Karin Troost. In the cockles surveys in Dutch coastal waters the survey takes place in May – June, whereas fisheries take place in late summer and autumn. Because the quota are set by the available stock and food reservation limits for birds, a prediction of fishable stock is made for September. Calculations are made using a Gompertz growth curve and existing data on summer mortality. None of the other participants use such methods but only report the encountered stock size. Ron Jessop was interested in doing the same for the Wash cockle stock. However, Roger Mann argued that such an exercise will only add an extra source of error.

Error estimates and variability in stocks

Roger Mann argued that variability in stock sizes, and the variance per year, may give more insight in developments than the mean alone. As discussed before, random sampling allows for a direct estimate of

standard error while for fixed grids error estimates need to be estimated using Monte Carlo simulations / bootstrapping procedures. The question was posed whether policy makers bother about confidence intervals. They probably do not, but confidence intervals may be important for fishermen that deal with imposed quota. In addition, James Strong would like to have more insights in the variability in brood stocks, as this may be a determining factor in predictions of seed mussel abundance and may furthermore determine whether a self-sustaining population is still viable.

3 Workshop 2: taxonomy and ageing of bivalve shellfish

3.1 Introduction

Presently, skills in ageing shellfish and determination of species are transferred from employee to employee during fieldwork. A more structural approach through annual meetings, where knowledge will be refreshed and mutually checked and verified, should improve methods and quality of the data. An initial team meeting was held in November 2010, with the use of practice material and reference books. With KBWOT funding, a more extensive construction was set up in November 2011, with participation from experts of the Dutch institutes IMARES and NIOO in the fields of taxonomy and ageing of (primarily) bivalve shellfish. Other benthic species, such as crustaceans, echinoderms and gastropods were also included.



Figure 2. Quiz on bivalve taxonomy.

Results consisted of an enhanced expertise in ageing and determination of shellfish species (and other common benthic species) at IMARES. This workshop brought together experts of IMARES and NIOO-CEME, and marks the beginning of an active maintenance of existing expertise at IMARES.

3.2 The workshop

The workshop was very successful in bringing together experts and research assistants in the WOT shellfish surveys and other projects involved in monitoring macrobenthic fauna. Among the participants there were also two experts in the field of taxonomy of macrobenthic invertebrates of the Monitor Taskforce of NIOO-CEME in Yerseke. A complete list of participants is given in the Appendix.

Introductory presentations were given by Kees Goudswaard about the IMARES shellfish surveys, by Joel Cuperus about the methodology of the IMARES benthos group in Den Helder, and by Angela Dekker about methods used at NIOO-CEME to identify bivalve and crab species.



Figure 3. Discussing how to recognize growth rings in *Cerastoderma edule* from disturbance rings.

Next, identification skills were tested by means of a quiz (Figure 2), in which 50 numbered specimens were presented, along with a list to fill in species names (Dutch and scientific names). Afterwards, Jack Perdon revealed the species names and led a discussion on which characteristics to consider. Discussions focussed on the different *Spisula* species *subtruncata*, *elliptica* and *solida*. *Spisula subtruncata* is a target species in the WOT programme. Another target species, *Ensis* sp., was discussed intensively. At present the different species of *Ensis*, namely *directus*, *siliqua* and *ensis*, are almost impossible to distinguish in the field where mainly the upper tips of the shells are harvested, and still difficult in the laboratory where intact specimens are opened to study taxonomic characteristics of the inner part of the shells. Joel Cuperus is working on a paper on identification of the different *Ensis* species.

Finally, skills in ageing cockles *C. edule* were tested by presenting all participants with a number of cockles from different age groups. Experts with many years of experience were present to give final conclusions on age classes (Figure 3). This exercise resulted in a lot of discussion between participants and was considered very useful for training and maintaining ageing skills. For the following years the aim is to organize similar workshops, which will grow into a better documented quality control instrument.

4 Conclusions

4.1 Conclusions of Workshop 1: Stock assessment techniques

1. The workshop was successful in bringing together experts in the field of shellfish stock assessments;
2. The workshop has led to comparisons between methods and sampling strategies in areas with different environmental characteristics (e.g. tidal regime, bathymetry, substrate);
3. Determining the efficiency of sampling gear is very important. There are different ways to estimate efficiency. Examples are given in this document;
4. Because of differences in efficiency and differences in specific advantages and disadvantages between gear types, using a combination of multiple gears may offer a higher level of information;
5. Whether to use a random or a fixed sampling grid depends mainly on the research question. Both approaches have advantages and disadvantages;
6. Stratification of the sampling grid (using a denser sampling grid in areas with a high expected abundance) is preferred and increases efficiency and accuracy, providing that the information basis for stratification is correct;
7. Although survey methods should always be optimal for the main species of interest, collection of additional information may give valuable information on variations in stock size in space and time. It is recommended to always do this for as far as possible in the available time;
8. Habitat mapping (maps that show different types of habitats, correlated with expected abundances of certain species) offers a lot of opportunities. It can be an important tool in optimising stratification but is mainly used to collect additional information to answer additional research questions;
9. Groundtruthing of results from aerial photographs, satellite images and acoustic maps is essential for a valid interpretation and consequent stratification and stock assessment and becomes increasingly important as more techniques such as acoustics and remote sensing are used;
10. Because habitat mapping using acoustic techniques can be time and money consuming, it is recommended to combine and share as much data and projects as possible.

4.2 Conclusions of Workshop 2: taxonomy and ageing

1. The workshop was successful in bringing together experts in the field of taxonomy of bivalves and other benthic macrofauna within the Netherlands;
2. The workshop has resulted in comparisons between techniques in identification of different research groups, and how these are dependent on specific research questions;
3. The workshop has contributed to a maintenance of the quality of species identification and ageing of cockles, by sharing techniques within and between research groups;
4. The workshop will lead to an improved quality of the shellfish surveys if regularly (bi-annually to annually) repeated;
5. Species that are specifically difficult to identify in the field are species of the genera *Ensis*, *Spisula*, and *Tellina*. Of these, many specimens of *Ensis* are impossible to identify to species level with 100% certainty in the laboratory;
6. *Ensis* cannot be identified to species level during the surveys and will be continued to be identified to genus level;
7. The workshop has resulted in an agreement on identification characteristics of bivalve species that are practical and reliable in the field;

8. In cases of even the mildest doubt specimens should be taken to the laboratory to be identified with more certainty using expertise of others and literature;
9. The workshop has resulted in an agreement on how to age cockles *C. edule*, and how to recognize false growth rings ('disturbance rings');

5 Recommendations for the WOT shellfish surveys

5.1 Stock assessment techniques

5.1.1 Sampling grid and confidence estimates

The sampling grids used in the WOT surveys of cockles and mussels in the Wadden Sea, and *Ensis* and *Spisula* in the North Sea coastal zone are currently fixed and stratified. It is important to realise that using a fixed grid has certain advantages and disadvantages compared to using a random grid. Fixed versus random sampling has been discussed during the workshop, and the outcome does not lead to a recommendation to change the set-up of the sampling grid. The fixed grid is suitable for the purpose of the surveys, and changing the set-up would lead to a break in trend. The remark was made that a fixed grid may lead to a higher level of uncertainty if the stock present is low. If the stock is too low, the species will not be encountered in most of the samples and it becomes impossible to estimate a confidence interval, or the confidence interval is extremely high. However, it is better to overestimate than to underestimate errors. Whether bootstrapping is the most suitable way to estimate confidence intervals, and whether methods used can be optimised, will be discussed further with experts in statistics and stock assessment.

5.1.2 New techniques

For the WOT shellfish surveys the basis for stratification in subtidal sampling (Dutch coastal zone) may be highly improved through habitat mapping using acoustic techniques. The possible application of multibeam surveys for this purpose will be studied in 2012, in cooperation with MUMM in Belgium, also funded by KBWOT Fisheries. The application of Remote Sensing for mapping of intertidal mussel and oyster beds seems promising but needs more developing. For the survey of Pacific oysters, a hydraulic grab will be developed in 2012, using the 'hydraulic patent tong' used by VIMS in the USA as an example.

5.2 Skills in identification and ageing

A workshop in taxonomy and ageing of bivalves is an efficient way to share and maintain knowledge and skills and should ideally be repeated every 1-2 years.

Acknowledgements

We are very grateful to all participants of the workshops, for their willingness to travel to Yerseke and to participate actively and enthusiastically. Special thanks go to people that helped organize the workshops: Sandra van Haarlem, Jack Perdon, Eva Hartog, Ad van Gool and Emiel Brummelhuis. The project was funded by the KBWOT Fisheries programme.

Signature

CVO Report: CVO 12.004
Project number: 4301900336

Approved by: Drs. F.A. van Beek
 Head WOT, Centre for Fisheries Research

A handwritten signature in black ink, appearing to be 'F.A. van Beek', written over a horizontal line.

Signature:

Date: 28th of March 2012

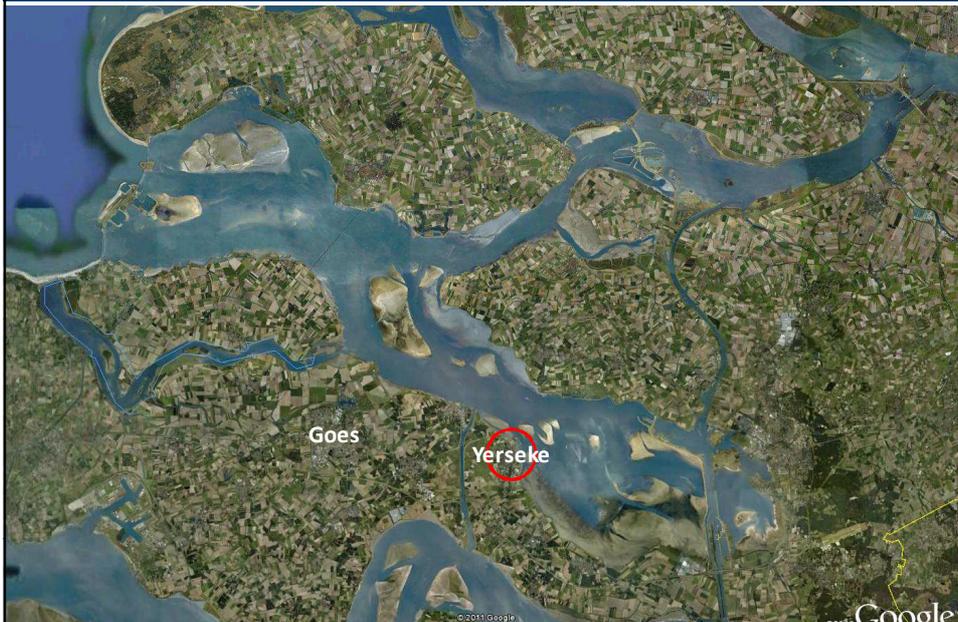
Appendix: all presentations

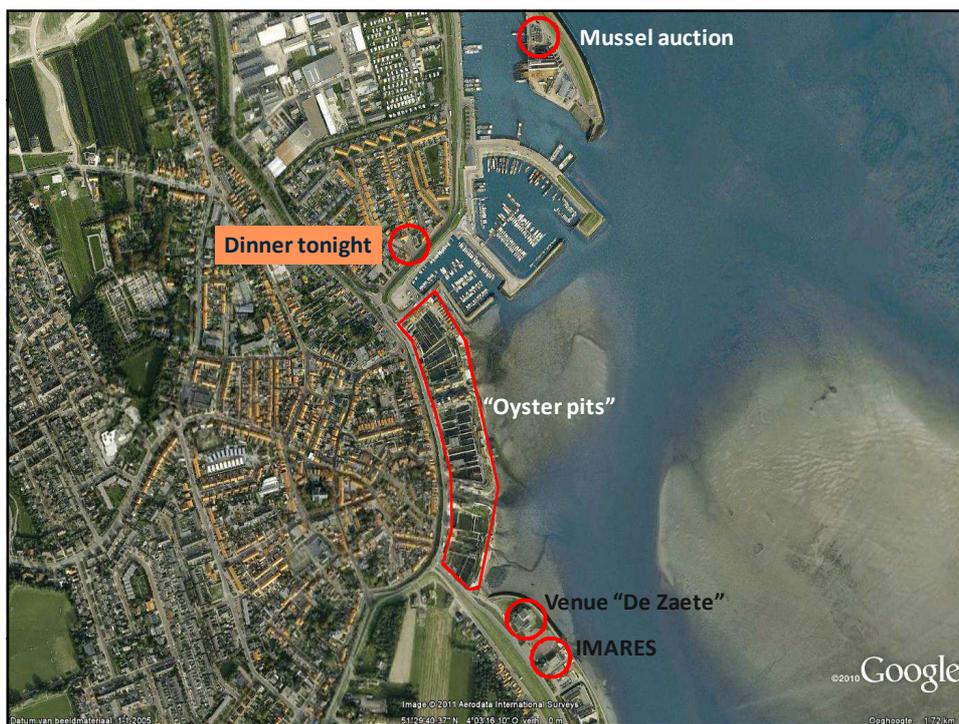
Shellfish Stock Assessments: State of the Art and New Techniques Yerseke, November 3 – 4, 2011

Karin Troost



Introduction to Yerseke





Practical:

Reimbursing travel costs when you get home:

- fill in form
- add original tickets
- send by mail to address indicated on form **before November 21st**

About the food:

- Who doesn't eat mussels?
- Those signed up for dinner today / tomorrow:
please choose a menu before lunch time today

Introduction to IMARES:
Institute for Marine Resources and Ecosystem Studies



Den Helder/ Texel

IJmuiden

Yerseke



Introduction to IMARES:
Institute for Marine Resources and Ecosystem Studies

Key focal research areas

- Ecology
- Environmental conservation and protection
- Fisheries
- Aquaculture
- Ecosystem based economy
- Coastal zone management
- Marine governance




Introduction to IMARES shellfish surveys

- Commissioned by Ministry for Economic Affairs, Agriculture & Innovation
- Main goal: fishery: fishing plans and management
- Optimal integration of nature conservation and fisheries
- Ability to assess effects of management measures and policy
- Additional surveys: subtidal mussel seed by MarinX



Introduction to IMARES shellfish surveys

	Wadden Sea	Ooster-schelde	Wester-schelde	Voordelta	Coastal Zone
Cockles	from1990 1379 pt	from1990 450 pt	from1992 250 pt	from1993 200 pt	
Mussels	from1994 1110 pt				
Spisula / Ensis				from1993 200 pt	from1993 650 pt
Pacific oysters	from 2011	from 2011	from 2011		

Why this workshop?

- Compare methods internationally
- Improve quality of surveys: efficiency and accuracy
- Keep stock assessments up to date
- Explore potential of new techniques

Participants



*Heike Büttger
Alexandra Markert*



James Strong



*Dvora Hart
Roger Mann*



Göktug Dalgıç



Vera van Lancker



Jean-Yves Stanisière



*Ron Jessop
Eden Hannam
Evonne Maxwell*

Participants

IMARES

Johan Craeymeersch
Narangerel Davaasuren
Kees Goudswaard
Jeroen Jansen
Marnix Poelman
Cor Smit

Douwe van den Ende
Carola van Zweeden
Jack Perdon

NIOZ

Eelke Folmer

NIOO-CEME
Daphne van der Wal

MarinX

Marnix van Stralen

Programme Thursday November 3rd

- | | |
|-------|--|
| 9:30 | Welcome and introduction |
| 9:45 | Presentations: Traditional Survey Techniques & Sampling Strategy |
| 12:15 | Lunch (here) & leg stretching |
| 14:00 | Presentations |
| 15:00 | Discussions |
| 17:00 | Walk to restaurant |
| 17:30 | Dinner at "De Sportvisser" in Yerseke |
| 21:00 | Bus leaves for Hotel |

Programme Friday November 4th

- 9:00 Bus from Hotel to Yerseke
- 9:30 Presentations: New Survey Techniques
- 12:15 Discussions
- 13:00 Lunch (here) & leg stretching
- 14:30 Presentations: Addressing Policy Questions Adequately
- 15:45 Discussions
- 16:30 Bus from Yerseke to Hotel
- 18:00 Dinner at Hotel



Let's start!



Workshop
Survey techniques for bivalve shell fish stocks

IMARES
Yerseke
3 - 4 November 2011

**Set-up and sampling techniques used to assess shellfish stocks
in Dutch coastal waters**

by
Marnix van Stralen



MarinX consultancy

Elkerzeeseweg 77, 4322NA, Scharendijke, NL
phone: +31 111671584
e-mail: marinx@zeelandnet.nl

History

- Early nineties: low shell fish stocks, especially in the Wadden Sea
- Cause: Lack of spat fall and ongoing natural mortality and fisheries
- Increased bird mortality
- Public awareness impact of shell fish fisheries (esp. cockle fishery) on nature

Shift in fisheries management

- From a fisheries approach towards the protection of the natural values.

New policy measures (in order of implementation):

- Reservation food for birds (Cockles, mussels for Oystercatcher and Eider ducks)
- Protection of habitats (old mussel beds, sea grass)
- Focus primary on intertidal areas
- Wadden Sea, Eastern Scheldt, North Sea coast.

For these measures:

- Information of shell fish stocks urgently needed.
- Not available (no ongoing survey-programs)

Challenge for science!

High variability in stocks

- In space (beds, patchiness within beds),
- In time (spat fall, impact of storm and severe winters)

Limited time between the survey and the fishery.

- Time need for fishing plans, licenses, appropriate assessments, juridical procedures.

Limited budgets

➤ Development of a variety of approaches and new techniques

= This presentation

Actual situation:

- Most surveys are carried out by IMARES
- For mussels IMARES + MarinX, in close cooperation with the mussel industry

Overview of the Dutch coastal waters and sampling stations for bivalve shell fish surveys in 2010.

The stations in de Oosterschelde and Westerschelde are not presented.



Assessment of Cockle stocks

- Mostly intertidal
- Wadden Sea, Delta region
- Annually in spring

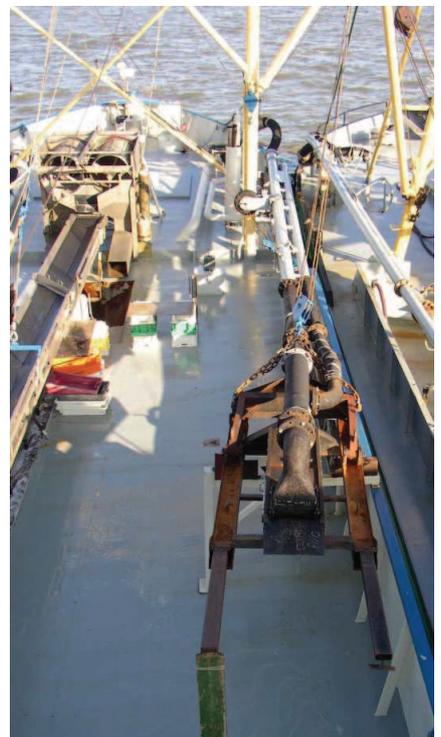
Start surveys in 1990

- During low tide, walking, using cores
- From small boats, special device,
“**kokkelschepje**” / “Cockle grab”
- 3 samples per station
= 0.1 m², depth 7 cm.



Half nineties:

- Improved relation with the cockle industry
- Survey carried out with commercial vessels
- Development of a modified suction dredge;
named “**Stempelkor**”
- Surface area sampled 0.4 m², depth 7cm,
- Samples sieved over 5 mm

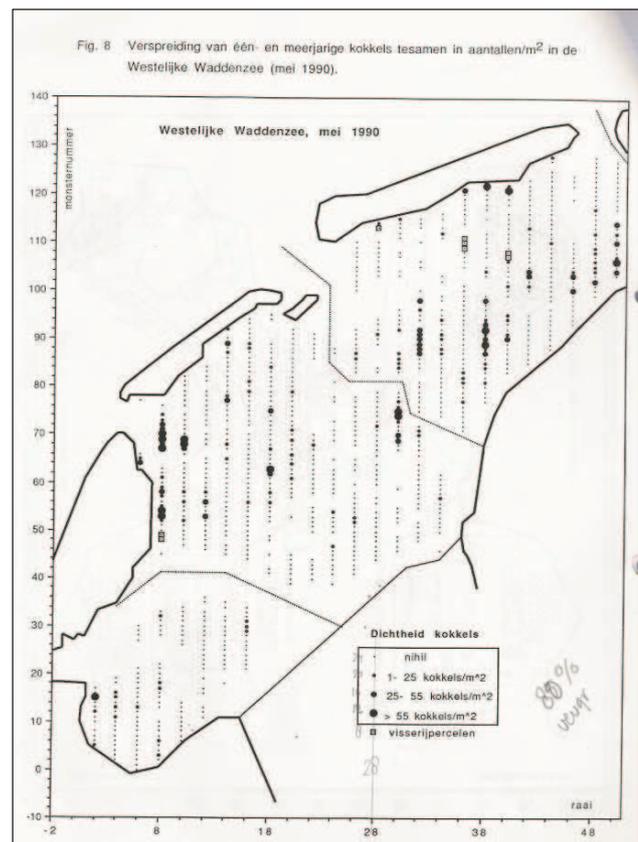




Assessment of Cockle stocks - Sampling strategy

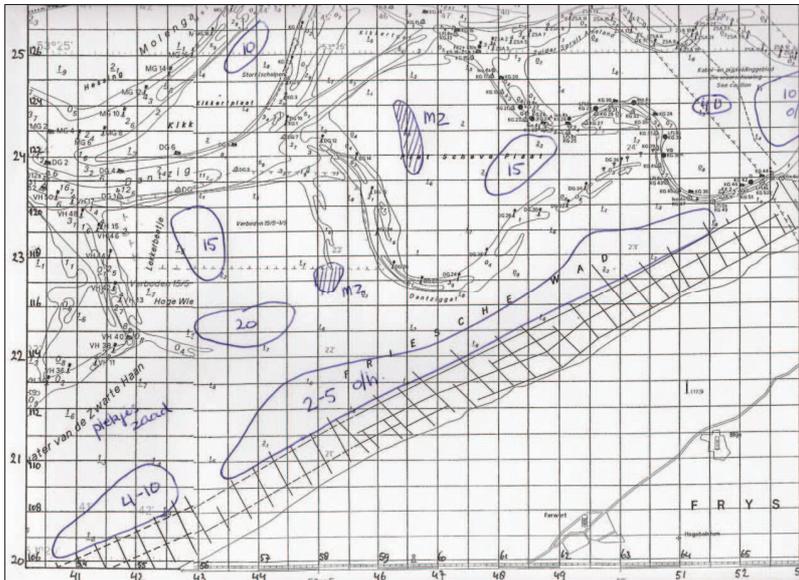
1990 till 1994

- No prior knowledge or information from the fishery (surveys seen as a threat)
- On transects
- Collected data:
Age or size classes,
Numbers and fresh weights
- Extrapolation data to stock estimates for September (Kamermans, yyyy)



Half nineties:

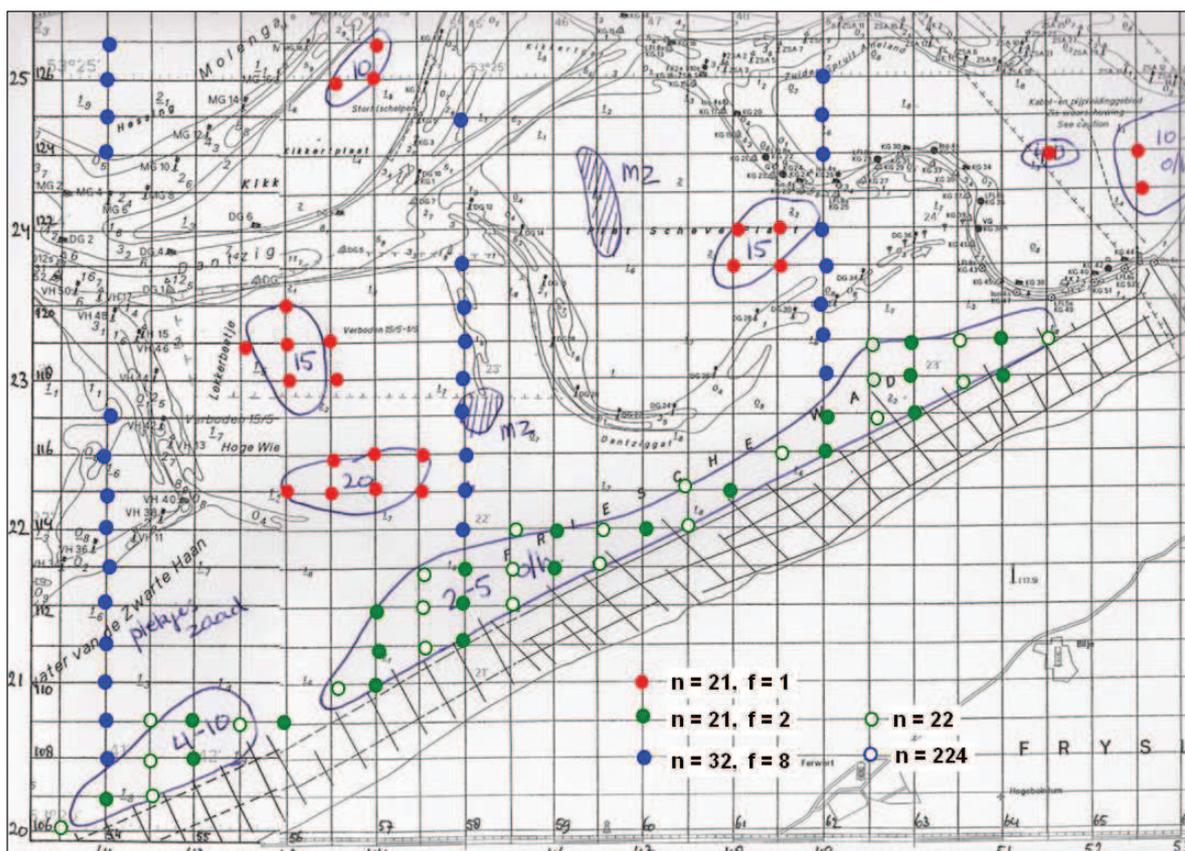
- Improved relation with the industry
- Surveys results from the industry available, detailed maps !
- Used for stratification



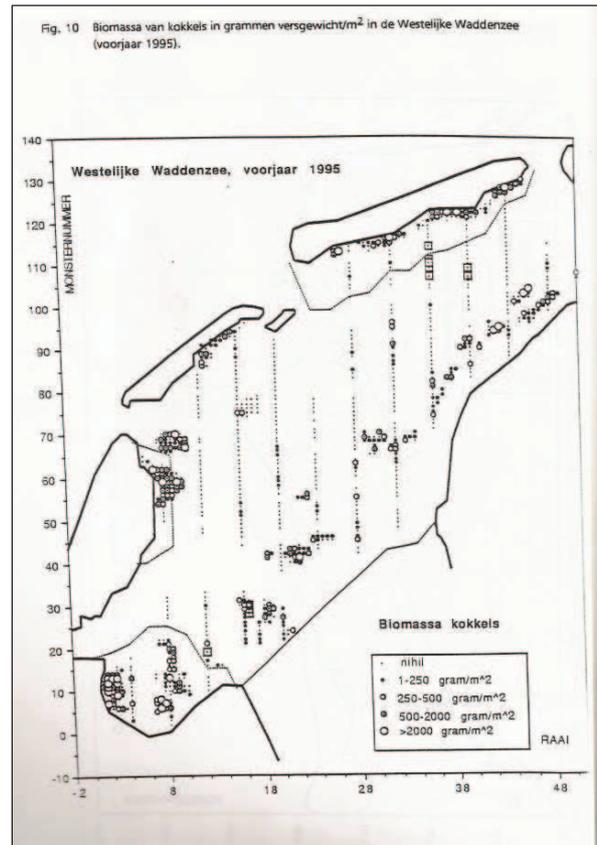
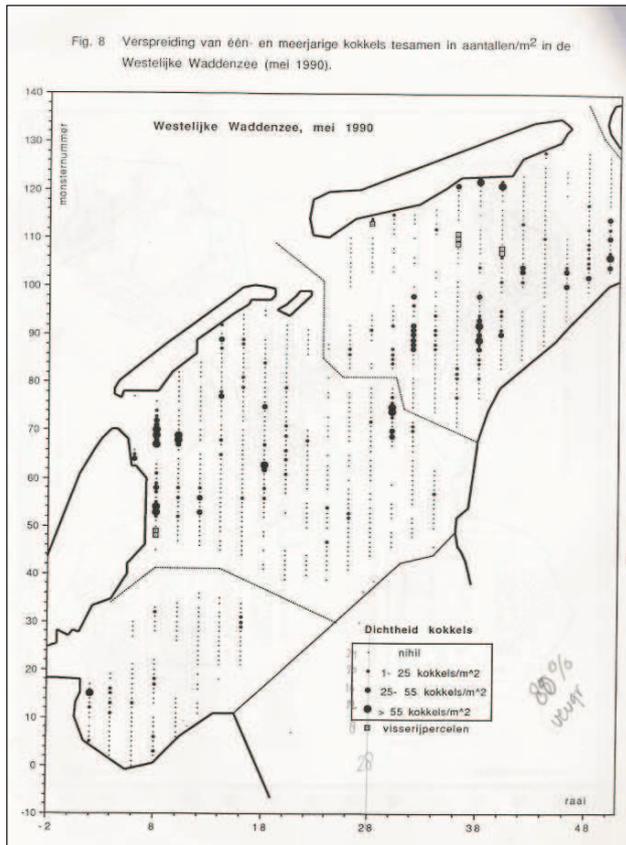
Survey map made by the industry (example).
Densities in number of cockles under one hand; MZ = mussel seed

10

Translated into a stratified sampling grid



Result: More detailed information of the size and distribution cockle beds and more reliable stock estimates especially on a local scale

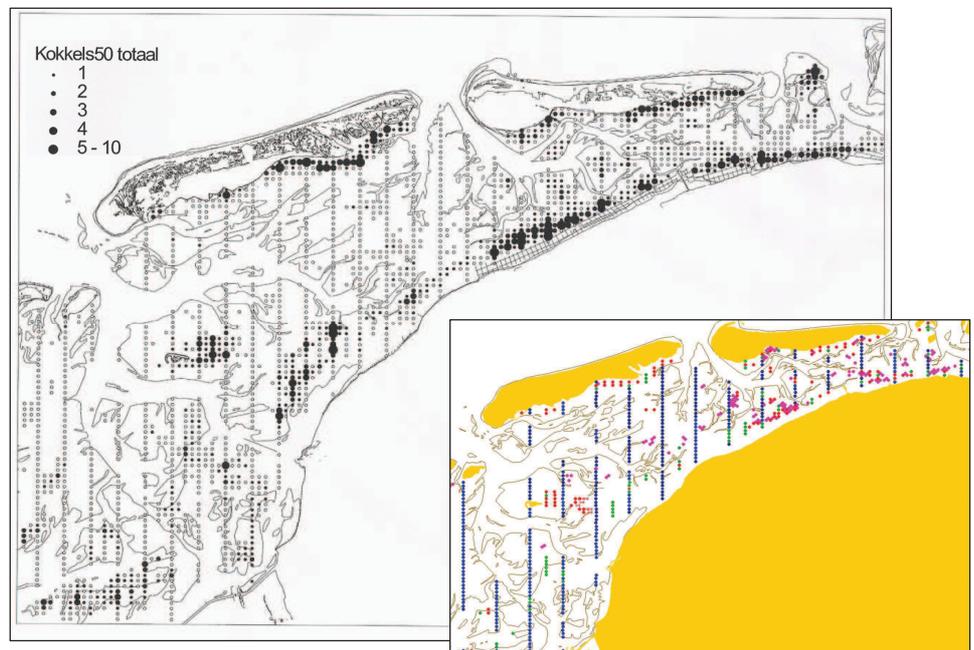


Cockle surveys today

- End of the mechanical cockle fishery in 2004
- Surveys still carried out with commercial dredger using the “Stempelkor”
- Stratification based now on the long term distribution of cockles
- In the Wadden Sea about 1300 stations, in the Delta region about 600 stations
- Combined with the stock assessment of intertidal mussels.

Number of years with cockles in densities > 50/m² between 1995 and 2004.

Sampling grid for cockles (blue, green and red) combined with the sampling grid for mussels (purple) in 2007



Validation survey results:

- Good fit with surveys by NIOZ on the tidal flat Balgzand (Wadden Sea) (Data Beukema, in Kamermans, yyyy).
- 95% Confidence Limits within 20% of the stock estimates (Monte Carlo analysis, Bult, yyyy)

Assessment of subtidal mussel stocks

Start surveys in 1992

- Western Wadden Sea (mainly)
- In spring and autumn

Techniques autumn

- Commercial **mussel dredge** and vessel
- Continuation of surveys as all ready carried out by the industry

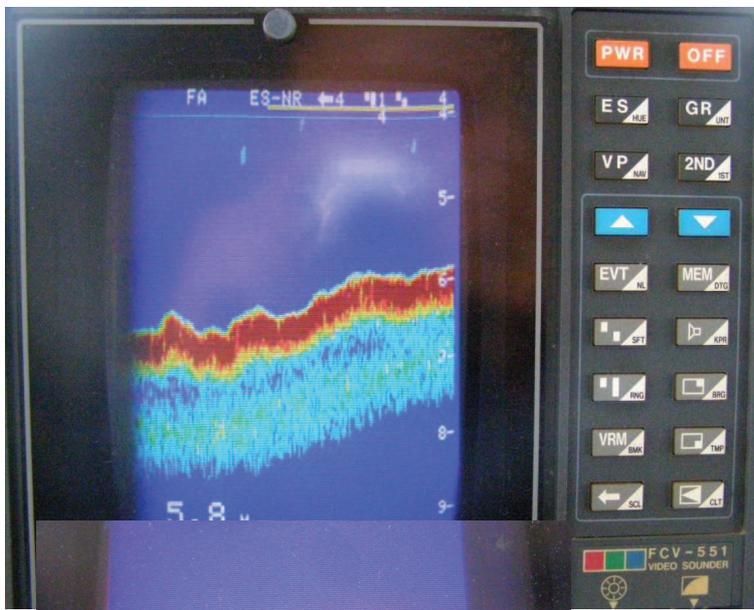
Strategy

- Explorative
- Focus on new spat.
- Together with experienced fishermen from the industry
- Prior knowledge: from fishery inspectors and shrimpers.
- Stock estimates by expert judgments of the participants.
Standard procedure.

Validation

- Mussel seed fishery as “check” on surveys:
Autumn estimates appeared to be conservative.

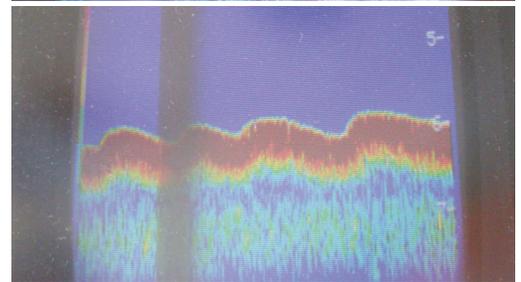
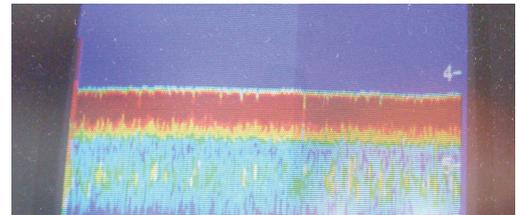
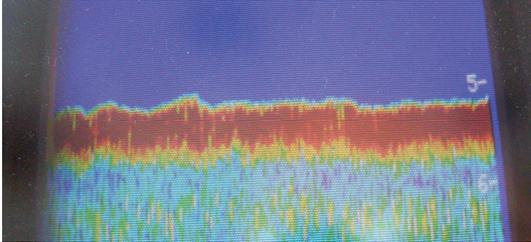
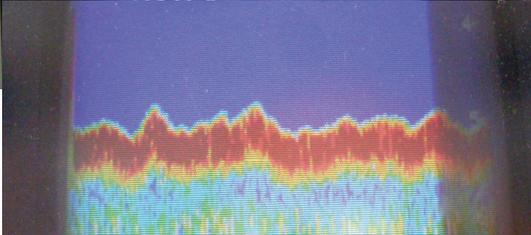




Echo sounding

← **Mussels**

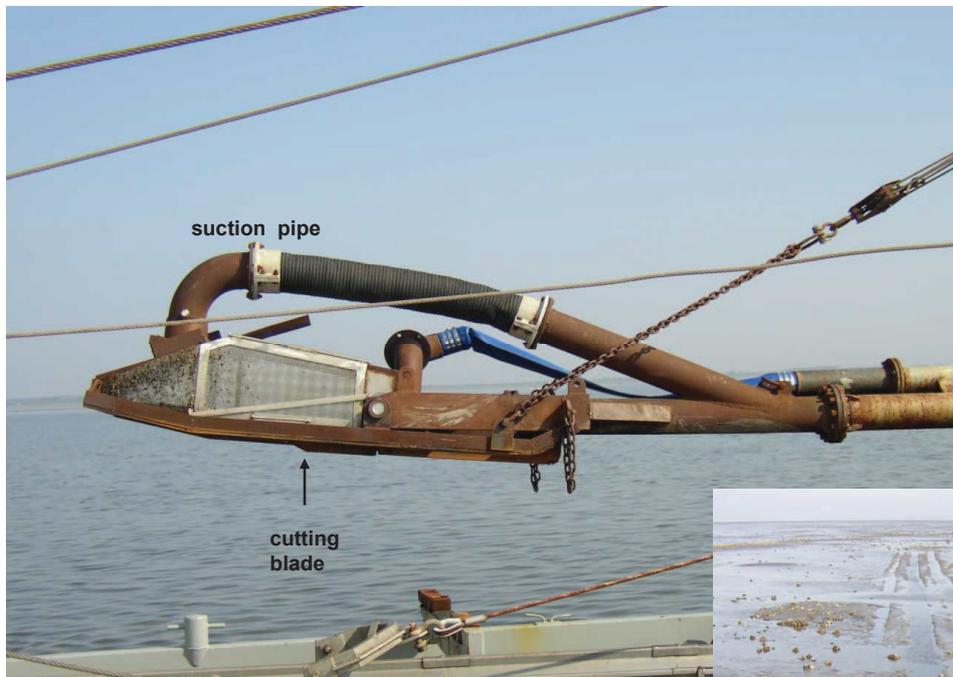
No mussels



Assessment of subtidal mussel stocks

Techniques spring

- Chartered cockle dredger
- **Modified suction dredge**
 - Cutting blade 20 cm width, 7 cm depth.
 - Mesh size 5 mm
 - Tow length is recorded from GPS / MaxSea,
 - Fished area of about 30 m² per sample.
 - Catches up to 500 liter (clay, peat, empty shells)
- Gear for sub sampling



Second conveyer belt with holes in it is used as sub sampling device



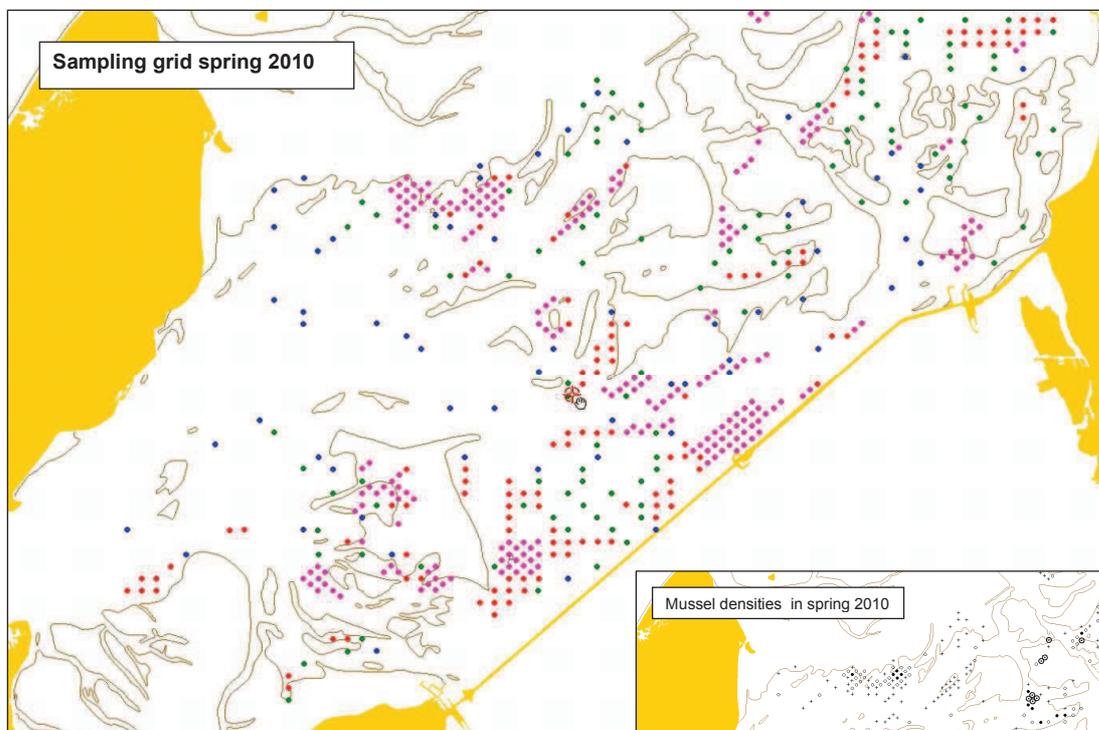
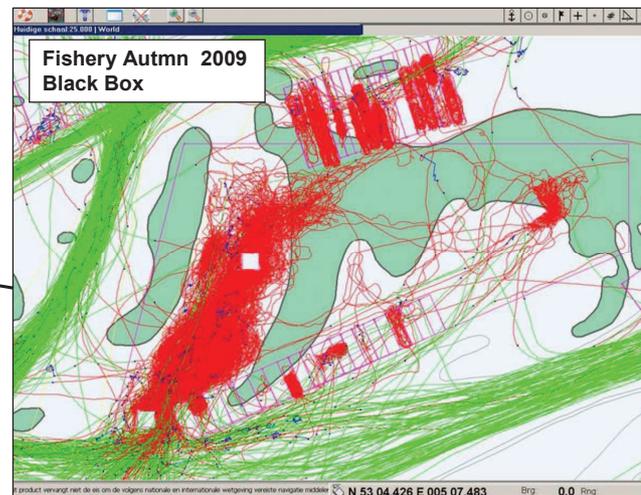
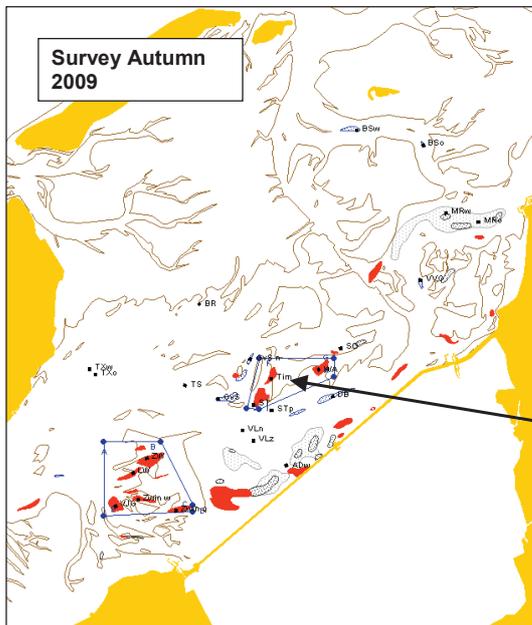
- For stations over 10 m water depth a **trawled dredge** “Bodemschaaf” is used

- Cutting blade 10 cm, 7 cm depth.
- The tow length, recorded by a measuring wheel and GPS / MaxSea (as check)
- Fished surface area is 8 - 10 m²

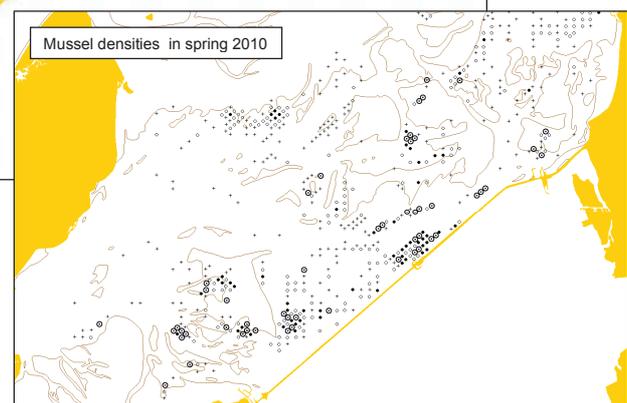


Sample strategy – spring

- Stratified sampling grid
 - Prior knowledge from autumn and earlier surveys,
 - Black box data autumn fishery



22



- 500 – 700 stations
- Quantitative stock estimates and maps
- Input for the fishing plans and the procedure for the fishery permits.

Mussels in other areas (Delta region)

- Only subtidal
- spat fall local and irregular (once in 3 - 4 year)
 - Last time Voordelta 2010
 - Oosterschelde 2009
 - Westerschelde 2008
- Surveys ad hoc.

Validation

- Mussel seed fishery as “check” on surveys:
Spring estimates fit well
- 95% Confidence Limits within 20% of the stock estimates
(Monte Carlo analysis, Wadden Sea, Bult, yyyy)



Commercial shell fish stocks in the Voordelta and along the North Sea Coast

- **Spisula** : Nineties (start surveys), since 2000 almost disappeared
- Now mainly **Ensis**
- Stratified sampling grid
- Trawled dredge “bodemschaaf”, mostly from research vessels
- Suction dredges (shallow areas Voordelta).
- For Ensis only the upper parts sampled and possibly partly missed.
- **Ensis dredge**
 - Most recent development (2008)
 - Surface area sampled 0.4 m²,
 - penetration depth 25 cm,
 - sieved over 5 mm
 - Still a prototype





Topics for further discussion

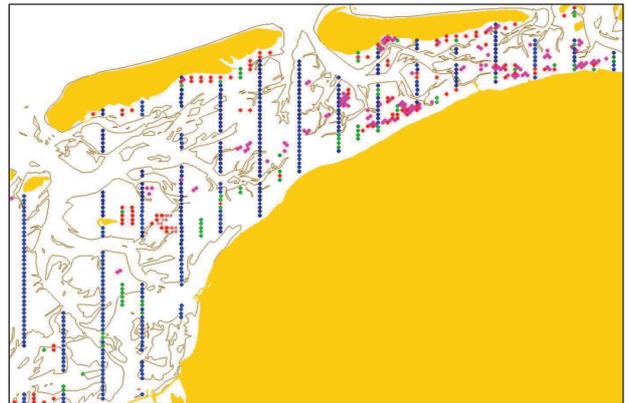
1. Stratified random versus grid based surveys. What is best?

Advantages stratified random

- Statistically most clean (no autocorrelation)
- On the long term the whole area is sampled.

Advantages grid based programs

- Relative easy to design.
- Less time consuming to sail
 - Less distance to sail
 - Less maneuvering
 - More easy tot adapt on drift to current and wind influences
- Repeated measures approach possible for stations sampled every year. ("eco plots")
- Historically grown.



2. Handling of samples:

- Stocks in space and time highly variable
- Questions afterwards on the level of sub area

Because of that

- **Priority to a high sampling density as possible**

And resulted in

- **Pragmatic handling of samples to save time**

=

- Lesser attention to non commercial species,
- No length distributions,
- No AFDW,
- No extra effort on rare species

Is this approach wise? Please comments and suggestions !!

Improving the Characterisation and Quantification of Seed Mussel Beds Around the Island of Ireland

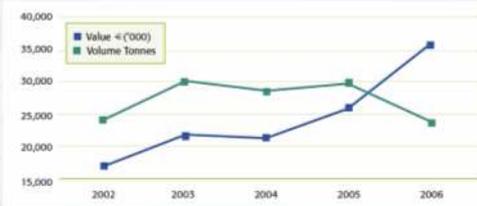
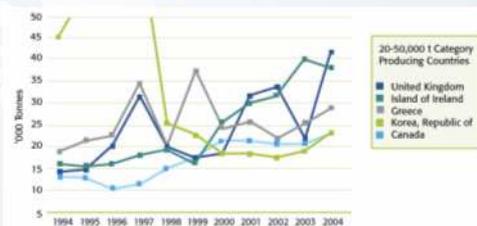
James Asa Strong
The Agri-Food and Bioscience Institute, Northern Ireland



INFOMAR
Integrated Mapping for the Sustainable Development of Ireland's Marine Resource



Bottom-Grown Mussel in the Island of Ireland

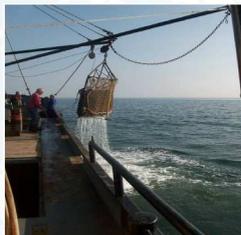


The Island of Ireland: Seed SA

- Agri-Food and Biosciences Institute, Northern Ireland (United Kingdom)
- Loughs Agency (NI/ROI cross boarder organisation)
- Bord Iascaigh Mhara (Republic of Ireland)



Loughs Agency NI/ROI



No initial acoustic survey.

Two commercial mussel dredges are deployed simultaneously from commercial vessels.

40-50 tows, approximately 300m in length.

Average densities of mussel seed are based on the area of the dredge tow length, the fullness of the dredge and the composition of the dredge contents.

Size frequency collected.

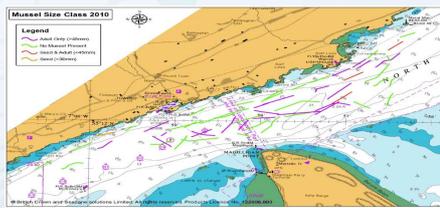


Figure 3. Size Classes of Mussel Present Within the Survey Area



Agri-Food and Biosciences Institute, Northern Ireland



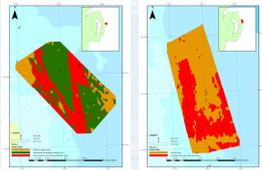
Initial acoustic (RoxSwath) survey

Second stage ground truthing with a single standardised industrial mussel dredge

Surveys since 2009 use OAA for distributing ground-truthing effort

Dredge efficiency integrated within calculations

Pieces per kg, strength, size and predator density is also measured.



Food and Biosciences Institute

Bord Iascaigh Mhara (Republic of Ireland)



Occasional use of an initial acoustic survey, but typically dredge-based

Ground-truthed with a 1 m naturalist dredge and grab

Tow lengths are 250 m and greater.

The contents of the dredge are assessed for 1) pieces per kg, size, waste content and predator abundance.



afbi Agri-Food and Biosciences Institute

Recommendations for Future Seed Mussel Stock Assessments

- Most of the methods only have a single sampling phase. An initial broad-scale survey, typically either an acoustic phase or data provided by industry ultimately benefits the stock assessment estimations.
- Acoustic collection is useful on smaller areas of seed mussel. The data are also more amenable to interpolation, production of surfaces and use in the Optimum Allocation Analysis, all of which significantly improve the final stock assessment value.
- Most methodologies use dredges. Scientific dredges, such as the naturalist dredge, are often much smaller generating greater variance within the assessments. Use of standard industrial mussel dredges has proven successful in better establishing 'extractable biomass'.

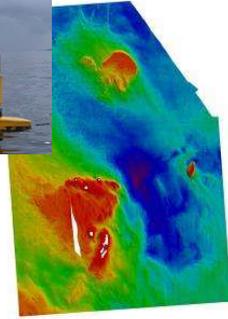


Recommendations for Future Seed Mussel Stock Assessments

- Communicating the results of the stock assessment to both resource managers and the industry also requires standardisation.
- Extra environmental parameters should be collected that aid understand of settlement processes and temporal variability
- Dredge efficiencies are highly variable between gear. These efficiencies have also been found to vary according to design, towing configuration, seed mussel density and substrata, hence more work is certain required to calibrate gear for local conditions.
- Understanding the relationship between *total biomass* (useful for the managerial and scientific requirements) and an *extractable biomass* (used for resource users) would be beneficial.



The Agri-Food & Bioscience Institute





Ron Jessop
Eastern Inshore
Fisheries and
Conservation Authority

EIFCA Shellfish Stock Assessments

EIFCA's primary research roles

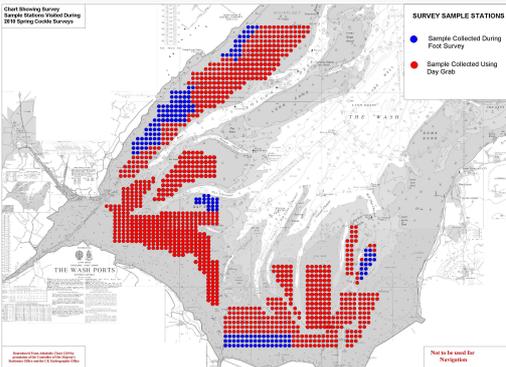


- Stock assessments
- Fishery impact assessments

Stock assessments - Cockles



Cockle Surveys in The Wash

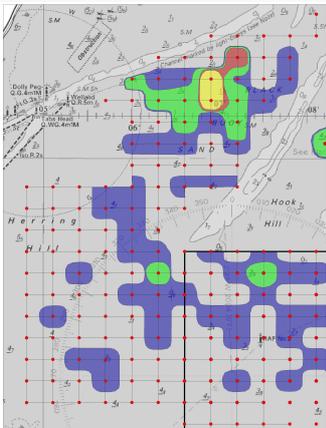


- Approx. 1,250 sample stations
- Regular grid (either 370x340m or 280x340m)
- Sampled either using Day grab or quadrat
- Survey in Spring and Autumn

Stock assessments - Cockles

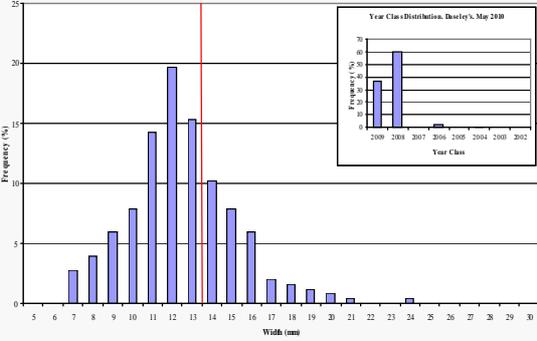


Cockle Distributions



Population Dynamics

Cockle Size Frequency, Daseley's, May 2010

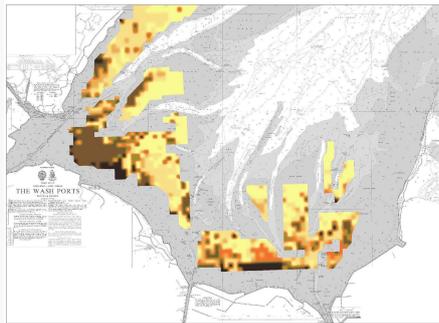


Additional data

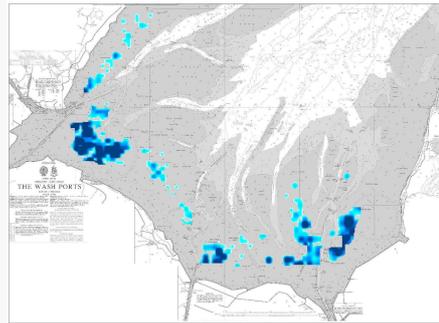


Habitat mapping – Sediment & Invertebrate data (*Arenicola*, *Lanice*, *Macoma*)

Sediment map



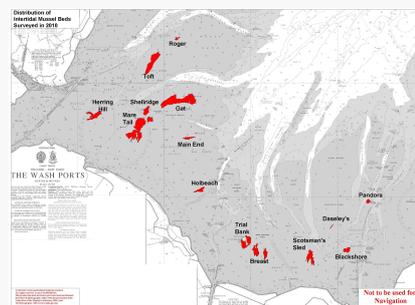
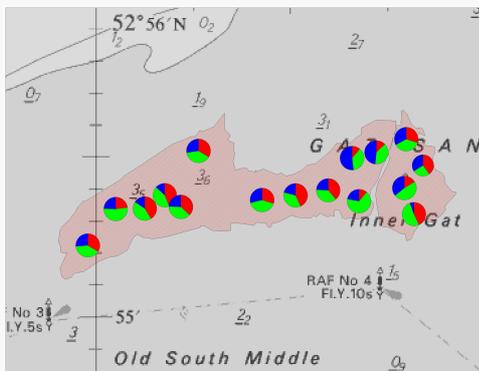
Macoma distribution



Stock assessments - Mussels



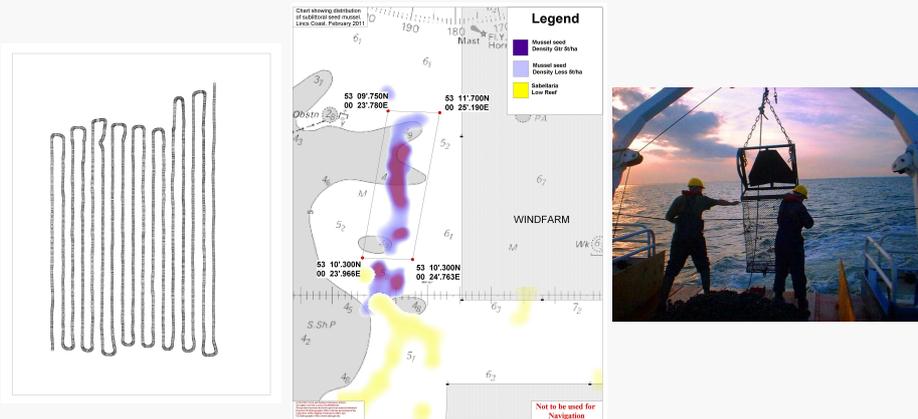
Intertidal Mussel Surveys



Stock assessments – Sublittoral Mussels



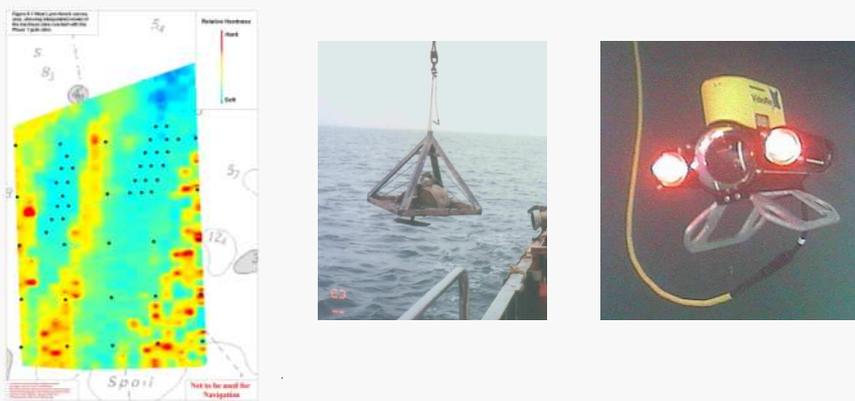
Use either Roxann AGDS or dredges to assess extent of beds



Stock assessments – Sublittoral Mussels



Use semi-stratified sampling with Day grabs and video footage to ground truth acoustic and dredge data



Environmental surveys



Habitat mapping – *Sabellaria spinulosa* reefs



Fishery impact assessments



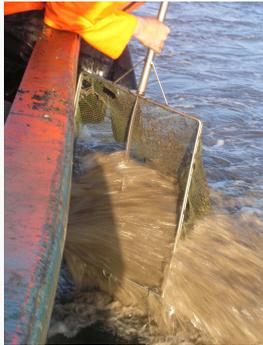
Cockle discard mortality studies



Fishery impact assessments



Cockle discard mortality studies



Fishery impact assessments



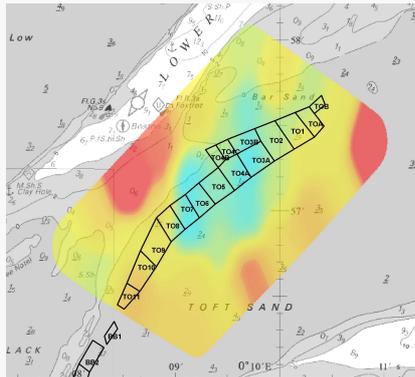
Environmental Impact of handwork cockle fishery



Environmental surveys



Water quality & food production



Supporting enforcement



Detection of "scrubbed" lobsters



Supporting enforcement



Detection of "scrubbed" lobsters



15 years of oyster stock assessment approaches in the Virginia portion of the Chesapeake Bay

Roger Mann
Virginia Institute of Marine Science
Gloucester Point, VA 23062 USA

rmann@vims.edu

http://www.vims.edu/research/units/labgroups/molluscan_ecology/index.php

Chesapeake Bay facts: the oyster resource in context



- 10,000 years old
- 298 km long
- 8484 sq km area
- 71.5×10^9 m³ volume
- 165,700 km² watershed
- Prior to colonial settlement (early 1600's) only native populations. Oyster intertidal!
- *The current upstream problem*
- 15 million people, add 3 million more by 2025
- 90% forested watershed in colonial times, 60% now
- *The current downstream status*
- The oyster harvest in 1885 would cover a soccer pitch 200m deep.
- The oyster population has declined over the past 120-150 y, the amount is open to debate, but probably >>90% reduction. The causes – harvesting, habitat loss, disease.
- The current Virginia annual dock side landings of oysters from the wild fishery are worth in the millions of dollars rather than tens of millions.
- The Chesapeake Bay is an irretrievably altered ecosystem, and we must set reasonable goals when we consider ecosystem management.

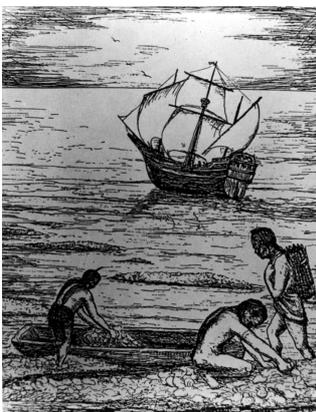
map copyright: Chesapeake Bay Foundation

Outline of the talk

- History of the Virginia fishery and associated assessment
- Examination of the various gear types and their limitations
- Original sampling design and designation of strata (1993-1998)
- A 15 year evaluation of the data (1996-2011) examples
 - Year and reef level data
 - Growth and mortality estimation
 - Recasting demographics for shell budgets
 - Recasting demographics for forward projections of stock size
- What is good and what is not that good about the assessment?
 - Stratification and post stratification of data – what is the question?
 - Survey redesign - developing a continuous data set for long term
 - Has the data been used in management? Can it be improved?
 - The compromise of limited funds and a fixed survey period.
 - Persistence of habitat (reef footprints) and the persistence of oysters
 - Is reef structure more stable over time that the live population?

History of the resource and the fishery

The post colonial settlers fished the resource without concern for long term sustainability. Huge quantities were harvested in the 1850-1920 time frame. 20th century oyster management was focused on short term public fishery – buy a license and work within limitations of season, time, location and gear. **NO ASSESSMENT AND NO QUOTA**



Art copyright to:
Virginia Institute of Marine Science.

Fishery for BOTH seed oysters (transplant) and larger direct market oysters.



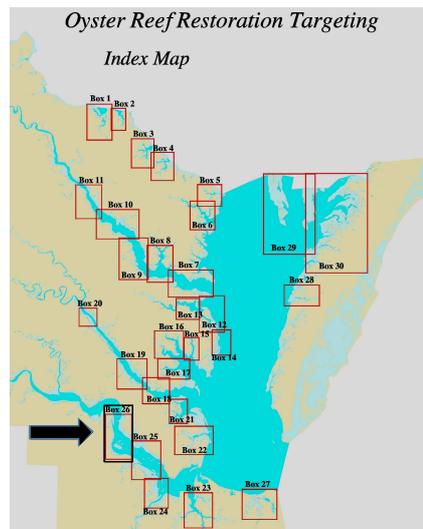
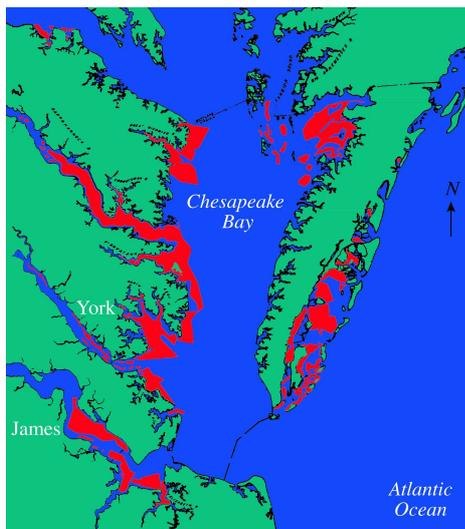
Mid 1950's - present, no limit on number of licenses, But gear and time restrictions apply. Significant disease and overfishing losses. **STILL NO QUOTA** except for seed oysters.



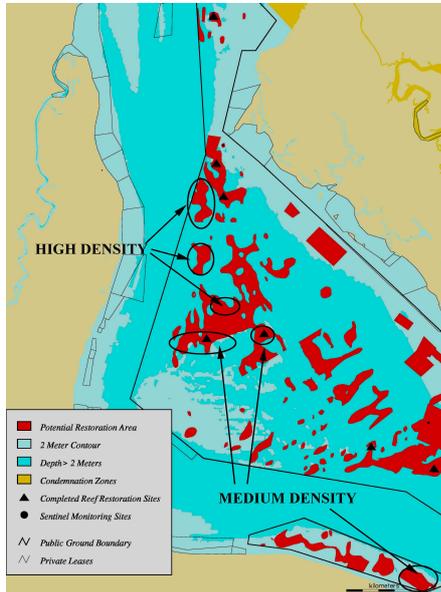
How significant was the habitat loss?
Consider simply the shell removal.

Art copyright to:
Virginia Institute of Marine Science.
Do not use without citation

Historical surveys and their use in designing current surveys.
Previous surveys by Baylor (1890's), Haven et al (1970's).
http://www.vims.edu/research/units/labgroups/molluscan_ecology/index.php



The James River as an example of the challenges in survey design:



An aggregation of reefs remaining from what was once a complex series of fringing and intertidal reefs within the river.

High density reefs (20-30% of the population in 2.5% of reef area) form the northwest boundary along the edge of the deeper channel.

Medium density reefs (15% of the population in 3.4% of reef area)

The majority of oyster habitat is low density reef (55-65% of the population in 94.1% of reef area).

BUT the majority of Baylor's survey is not continuous oyster habitat – it is small reefs dispersed over a large area.

We assigned strata based on historical fishery boundaries (enforcement issue) and assumed random distribution within these.

Total reef area = 11,000 acres = 44×10^6 sq. m

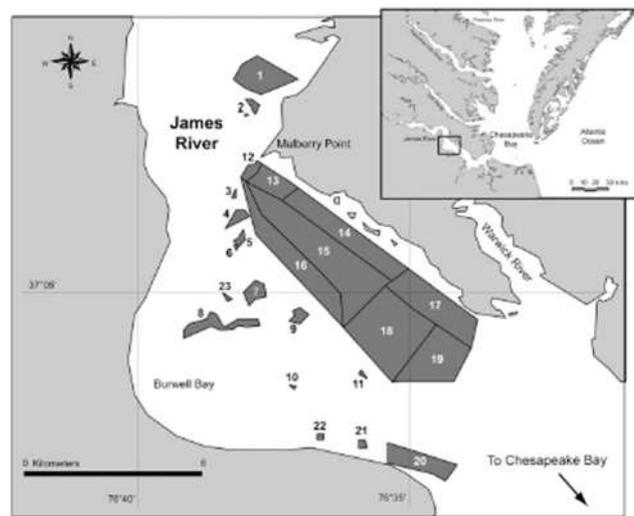


Figure 1. Map showing the locations of the 23 reefs sampled during the patent tong survey in the James River, VA on an annual basis 1993 to 2006. (1) Upper Deep Water Shoal, (2) Lower Deep Water Shoal, (3) Upper Horsehead, (4) Middle Horsehead, (5) Lower Horsehead, (6) Moon Rock, (7) V-Rock, (8) Point of Shoal, (9) Cross Rock, (10) Shanty Rock, (11) Dry Lumps, (12) Mulberry Point, (13) Swash, (14) Upper Jail Island, (15) Swash and Mud Slough, (16) Offshore Swash, (17) Lower Jail Island, (18) Offshore Jail Island, (19) Wreck Shoal, (20) Day's Point, (21) Hotel Rock, (22) Snyder's Rock, and (23) Triangle Rock. The numbering system will be used throughout the text and figures.

Survey gear types and limitations: modest vessel size (42' or 14m)

- Dredges- swept area approaches, but unknown and variable efficiency*
- Patent tongs – defined area (✓) but unknown efficiency
- Hydraulic tongs – defined area (✓), separates collection from retrieval action, heavy, assumed high efficiency easy to verify visually, high sampling rate (100/day).
- 6 week time period: October-November
- I can expand on this for other fisheries where we calibrate dredges if there is time.



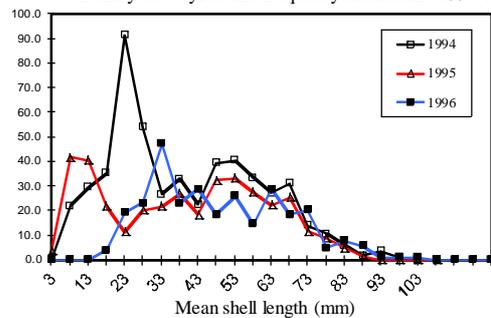
Sampling design and designation of strata: (developed 1993-1998, stable since that time)

- Strata (polygons or reef systems defined by historical area).
- Random sampling in 23 reef systems: 1993-onwards.
- One sq.m with a hydraulic patent tong.
- Adequacy of sampling assessed by plotting n (sample) versus s.e of mean. Simple, real time.
- Count and measure all oysters.
- Count and measure all articulated valves.
- Record volume of shell (both black “buried” and brown “surface” shell).

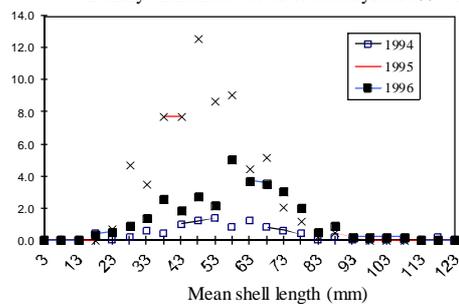
A 15 year evaluation of the utility of the data (1996-2011)

- Basic reef level information and single year events. Add them together and a working population assessment results.
- Age and growth – demographics, shell signatures, isotopes, recasting length data with large n values and starting again with year classes instead of size classes.
- Mortality is estimable, limited year classes, scary!
- Shell budgets (but that is the next presentation)
- Replacement ratios
- Forward estimation of age structure and optional quota with year specific disease impacts.
- **VERY IMPORTANT** – These calculations must be **TOOLS** that can be understood by the regulators and the end users – otherwise they will not be accepted.
- Still no quota, but the program works because we have engaged the industry, and they have input in the management process.

Density: live oyster size frequency distribution: 1994-1996



Density: articulated valves of dead oysters:1994-1996

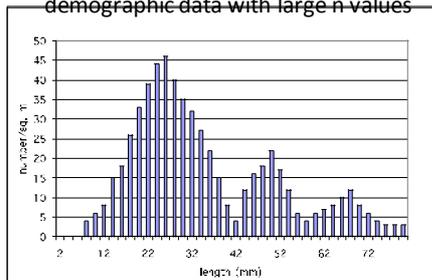


Single events: an example
1995, mid summer rain,
mortality and recruitment
events.



Can we estimate growth, age, and mortality?

Estimating age classes from demographic data with large n values



The data fit with $n > 22,000$, $R^2 = 0.934$

$$y = mx + c$$

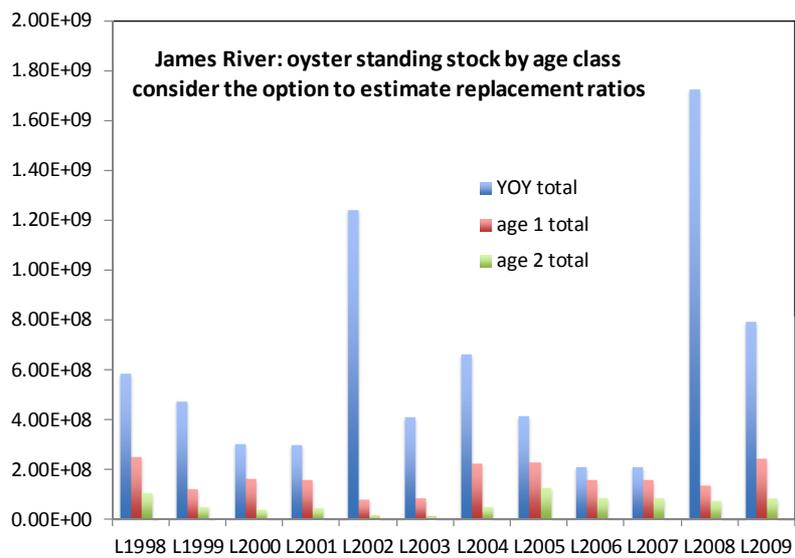
$m = 21.6$ and $c = 30.22$
 age (y) length (mm)
 0.33 37.3
 1.33 58.9
 2.33 80.5
 3.33 102.1
 4.33 123.7

age	1998	1999	2000	2001	2002	2003	2004	2005	2006
0.33	79.1	166.8	166.9	160.8	538.6	390.9	170.1	64.0	64.1
1.33	94.5	56.0	108.7	114.3	45.6	51.1	135.6	162.3	112.1
2.33	57.0	33.4	37.2	49.2	14.9	10.1	28.1	77.6	87.9
3.33	9.7	6.8	9.6	10.4	4.5	1.8	6.4	11.2	25.1
4.33	1.5	0.1	0.6	0.5	0.6	0.2	0.9	0.9	3.0
	241.8	263.1	322.8	335.2	604.1	454.0	341.1	316.0	292.3

Recast the length demographic (#.m⁻²) as age: data from reef #6, Mann et al 2009

Estimating mortality and contribution to shell base volume (more on this in the next presentation)

1999 year class - serial contribution (L) to the shell base							
age	n	mortality	shell individual		shell total		year added to shell base
			low	high	low	high	
0.33	166.8						
1.33	108.7	58.2	0.02	0.06	1.25	3.32	2000
2.33	49.2	59.4	0.06	0.11	3.40	6.64	2001
3.33	4.5	44.7	0.11	0.19	5.00	8.33	2002
4.33	0.2	4.4	0.19	0.28	0.82	1.23	2003



James River standing stock and mortality: simple estimator for management*

	2002	2003	2004	2005	2006	2007	2008	2009
YOY total	1.2E+09	4.1E+08	6.6E+08	4.1E+08	2.1E+08	2.1E+08	1.7E+09	8.0E+08
age 1 total	8.1E+07	8.6E+07	2.3E+08	2.3E+08	1.6E+08	1.6E+08	1.4E+08	2.5E+08
age 2 total	2.1E+07	1.7E+07	5.4E+07	1.3E+08	8.7E+07	8.7E+07	7.7E+07	8.9E+07
(No-N1)/No	0.87	0.79	0.37	0.43	0.63	0.45	0.51	0.37
500/bu								
age 2 total	4.2E+04	3.4E+04	1.1E+05	2.6E+05	1.7E+05	1.7E+05	1.5E+05	1.8E+05

*Footnote: we can project a range of disease related mortalities in advance of the fishing season based on water temperature and salinity, and past records. Then we use this value to generate estimates of harvest for the following season (???QUOTA???)

Journal of Shellfish Research, Vol. 29, No. 4, 867–888, 2010.

**MANAGEMENT OF THE PIANKATANK RIVER, VIRGINIA, IN SUPPORT OF OYSTER
(*CRASSOSTREA VIRGINICA*, GMELIN 1791) FISHERY REPLETION**

JULIANA M. HARDING,^{1,*} ROGER MANN,¹ MELISSA J. SOUTHWORTH¹
AND JAMES A. WESSON²

¹Department of Fisheries Science, Virginia Institute of Marine Science, College of William and Mary, Gloucester Point, VA 23062; ²Virginia Marine Resources Commission, 2600 Washington Avenue, Newport News, VA 23607-0756

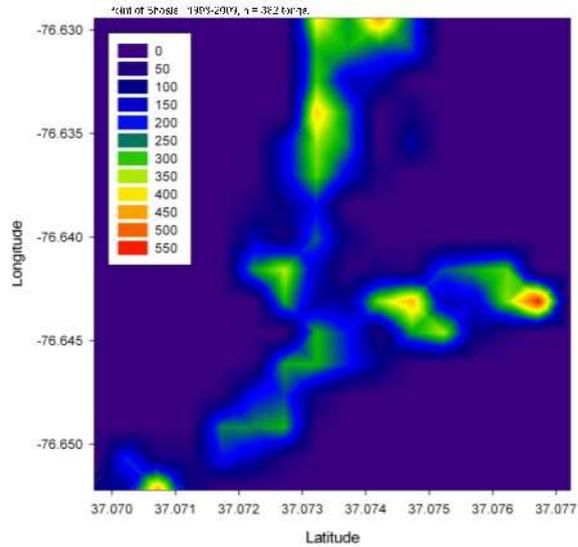
ABSTRACT The Piankatank River is a trap-type estuary on the western shore of Chesapeake Bay that has been managed for seed oyster production since 1963. Market oyster production in the river is minimal. Repletion efforts include shell planting and seed removal. We describe sequential changes in population demographics and habitat in relation to repletion activities on eight Piankatank River public oyster reefs from 1998 through 2009. Two reef groups (northern and southern) may be distinguished by density (oysters/m²), biomass (g dry tissue weight), and shell volume (L/m²) data. Age-at-length relationships were estimated from demographic data using a quadratic model. Observed mortality rates were high, and age 3+ oysters were essentially absent. A strong recruitment signal was observed in 1999 and 2002. Between 1998 and 2009, about 30% of the live oysters in the river were harvested as seed, corresponding to ~7.5% of the total shell base in an average year. Typically, for every 5 bushels of shell planted, 1 bushel of seed was harvested (20% return). Even with shell planting (~10 L/m²/y), the river shell budget showed a deficit with respect to the accretion rate required to balance sea level rise and natural degradation processes. During the study period, the mean river recruit-to-stock ratio was ~4. The unusual and consistently high recruit-to-stock ratios suggest that management for modest continuous seed removal may be accomplished without shell planting. Annual stock assessment to identify low recruitment years is recommended as a method to adjust annual seed harvest quotas.

KEY WORDS: Eastern oyster, *Crassostrea virginica*, population demographics, mortality, recruitment, repletion, shell budgets, Piankatank River, Virginia, fishery management

A rotational harvest plan to maximize seed oyster production and conserve shell

What is good and not so good about the assessment?

- Stratification and post stratification of data – what is the question?
- Survey redesign - developing a continuous data set for long term (decades)
- Has the data been used in management? Can it be improved?
- The compromise of limited funds and a fixed survey period.
- Persistence of habitat (reef footprints) and the persistence of oysters
- Is reef structure more stable over time than the live population?



Concluding thoughts.

- The surveys, despite their limitations, have given us a working long term knowledge that has been used in management.
- The industry and the regulators understand it and use it as a management tool.
- Improvements remain a compromise in that the need is to complete a survey of a known stock in a known area in a fixed time frame with a fixed budget.
- None of this would have been possible without an amazing field crew who do all the hard work. Thanks to my colleagues Jim Wesson, Melissa Southworth, Juliana Harding, Alan Godshall, Vernon Rowe, John Erickson, Adam Crockett, and Erin Reilly.
- Thanks to Commonwealth of Virginia, National Oceanic and Atmospheric Administration, Chesapeake Bay Program Office, and Environmental Protection Agency for funding.
- Thanks to Karin Troost and IMARES for the invitation and being such gracious hosts.
- Thank you for listening—questions?





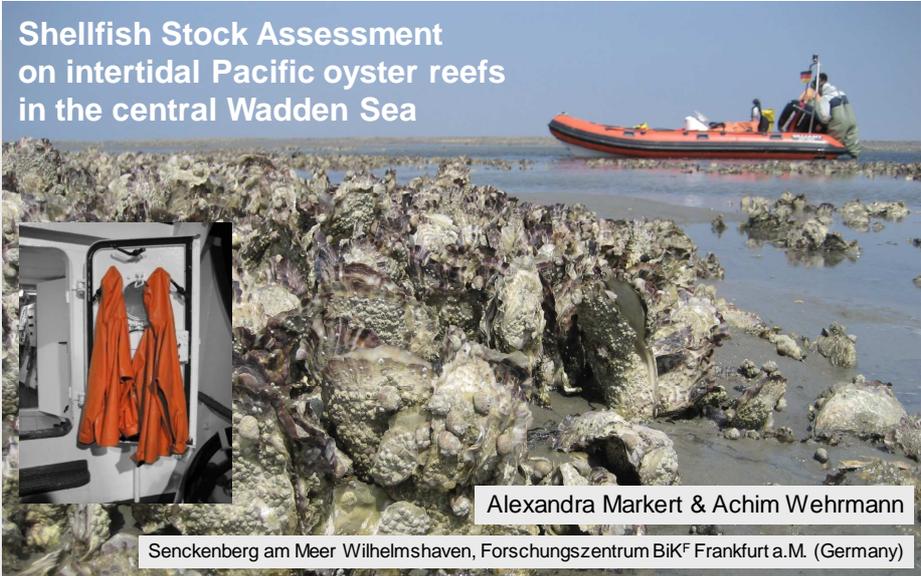
Leibniz

SENCKENBERG
research



BiK Biodiversität und Klima
Forschungszentrum

Shellfish Stock Assessment on intertidal Pacific oyster reefs in the central Wadden Sea



Alexandra Markert & Achim Wehrmann

Senckenberg am Meer Wilhelmshaven, Forschungszentrum BiK Frankfurt a.M. (Germany)

International Workshop on Shellfish Stock Assessments • Yerseke Nov 2011 • amarkert



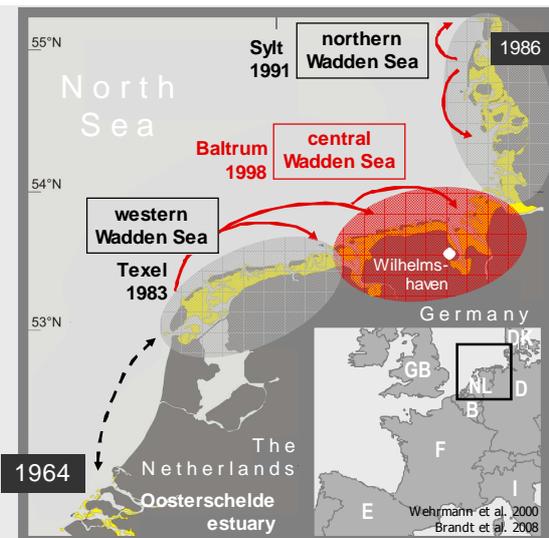
Leibniz

SENCKENBERG
research



BiK Biodiversität und Klima
Forschungszentrum

Crassostrea gigas (Pacific oyster) Introduction and spread



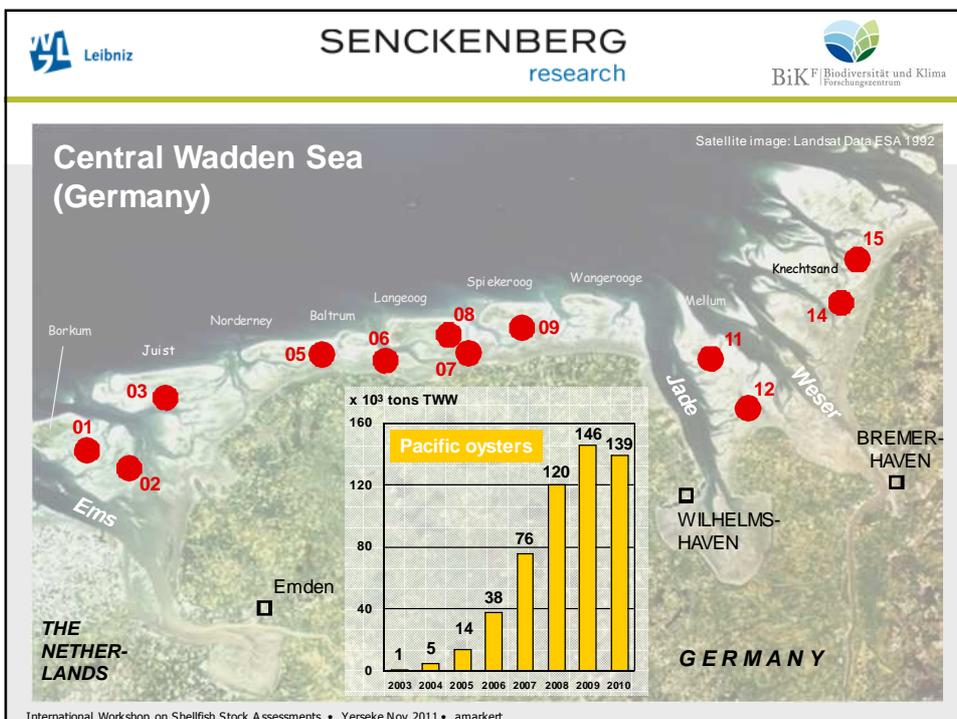
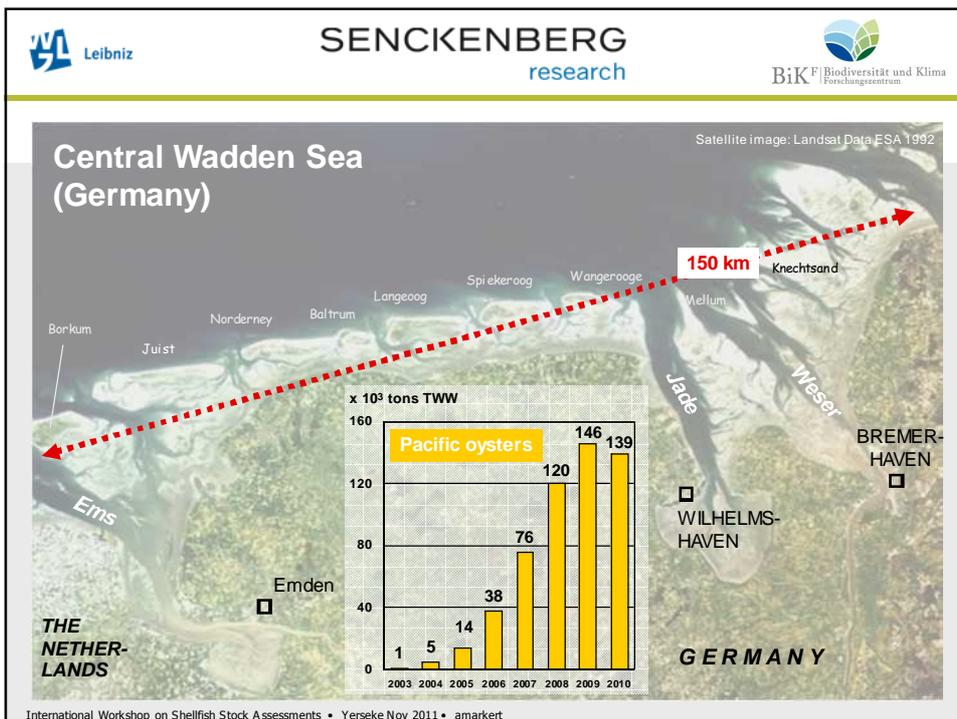
Wehrmann et al. 2000
Brandt et al. 2008

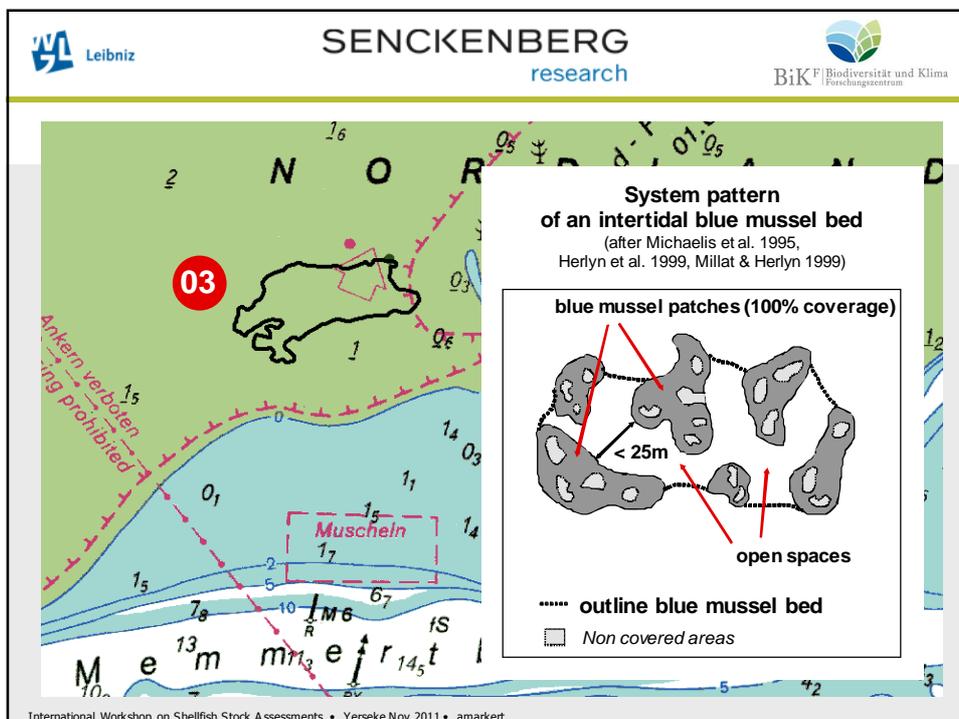
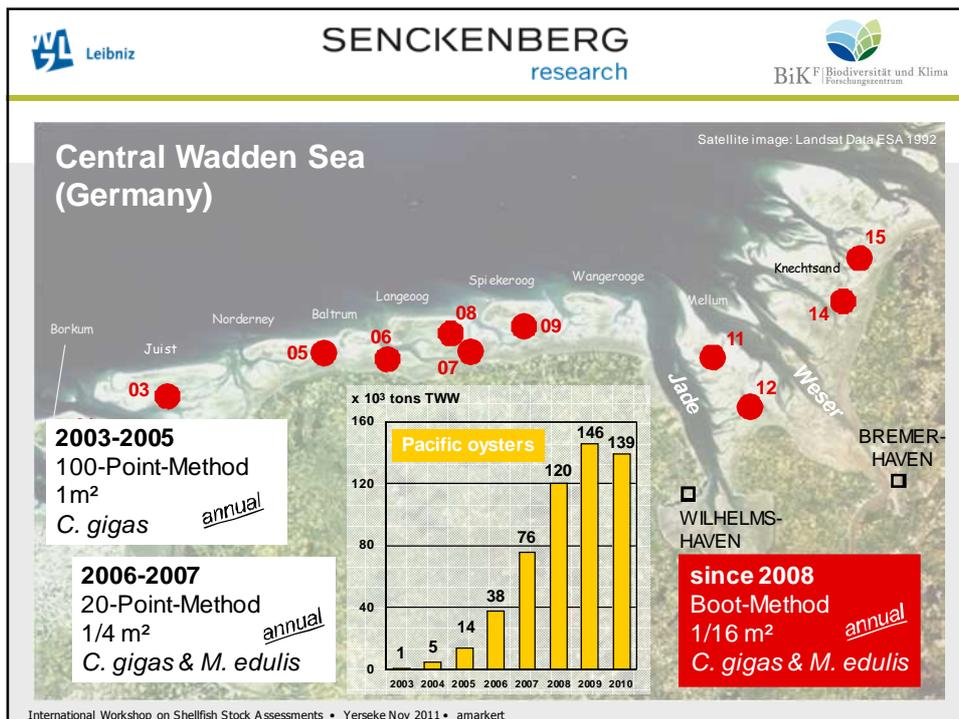
Initial transport vector
aquaculture and mussel seed transfer

Secondary transport vector
coastal larval drift



International Workshop on Shellfish Stock Assessments • Yerseke Nov 2011 • amarkert





Leibniz **SENCKENBERG** research **BiK^F** Biodiversität und Klima Forschungszentrum

International Workshop on Shellfish Stock Assessments • Yerseke Nov 2011 • amarkert

Leibniz **SENCKENBERG** research **BiK^F** Biodiversität und Klima Forschungszentrum

System pattern of an intertidal shellfish field
 (after Michaelis et al. 1995, Herlyn et al. 1999, Millat & Herlyn 1999)

Shellfish patches (100% coverage)

..... outline shellfish bed/reef

International Workshop on Shellfish Stock Assessments • Yerseke Nov 2011 • amarkert

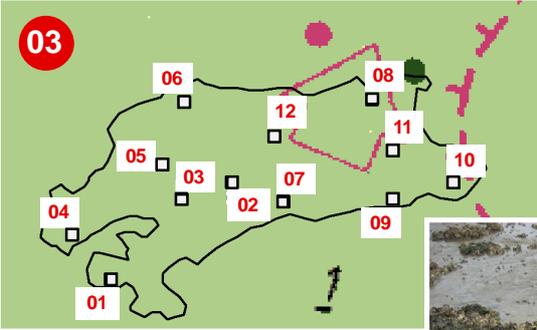


Leibniz

SENCKENBERG
research



BiK Biodiversität und Klima
Forschungszentrum



12 stations
Shellfish patch (100%)

25 x 25 cm
1/16 m²
0.0625 m²




International Workshop on Shellfish Stock Assessments • Yerseke Nov 2011 • amarkert

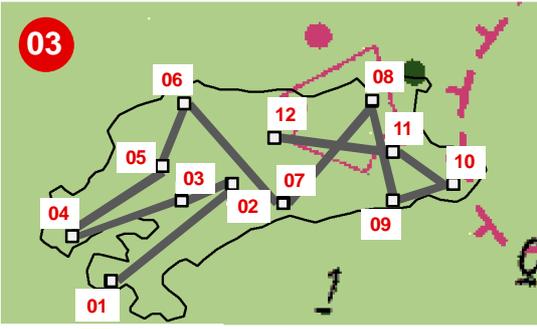


Leibniz

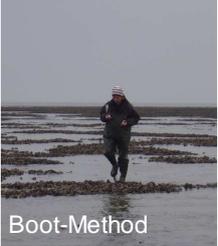
SENCKENBERG
research



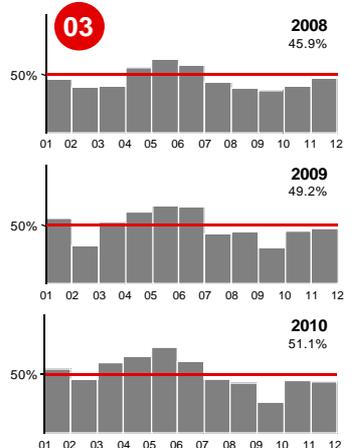
BiK Biodiversität und Klima
Forschungszentrum



11 distances
Coverage (%)
(steps on patch/total steps)



Boot-Method



Year	01	02	03	04	05	06	07	08	09	10	11	12	Total
2008	45.9%												
2009	49.2%												
2010	51.1%												

International Workshop on Shellfish Stock Assessments • Yerseke Nov 2011 • amarkert



SENCKENBERG

research



Sample processing (lab)

- rinsing samples (0.5 mm) and sorting species

Pacific oyster

Blue mussel

Shellfish patch (100%)





- shell length (**live** and **dead** individuals)
- biomass (total wet weight, weight of cocked flesh, shell weight)

Associated macrofauna *Decapod crabs: carapax width (mm) and sex*

Presence of conspicuous macrofauna (Bivalvia/cockles, Hydrozoa, Anthozoa, Phytobiota, Neobiota



International Workshop on Shellfish Stock Assessments • Yerseke Nov 2011 • amarkert



SENCKENBERG

research



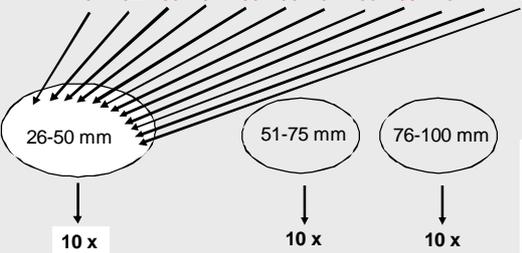
Pacific oyster

Blue mussel

Biomass (TWW, WCF, SW)

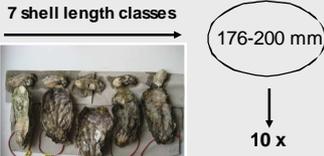
7 shell length classes
(26-50, 51-75, 76-100, 101-125, 126-150, 151-175, 176-200)

stations 01 02 03 04 05 06 07 08 09 10 11 12



Biomass (TWW, WCF)

5 shell length classes
(11-20, 21-30, 31-40, 41-50, 51-60)





1

2

3

4

5

6

7

8

9

10

Shell length (mm)

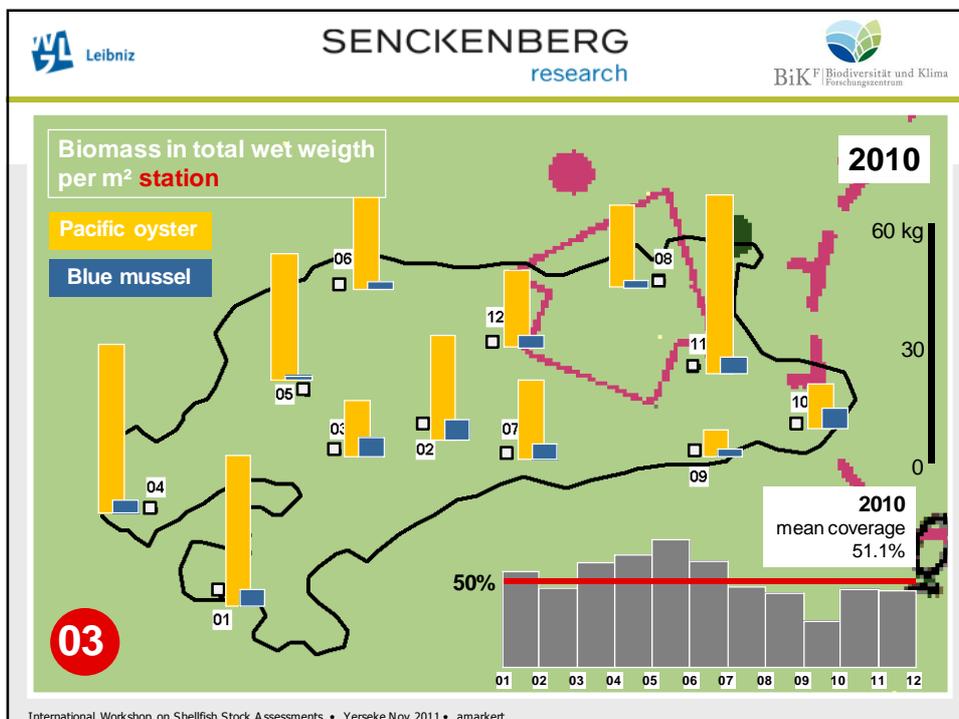
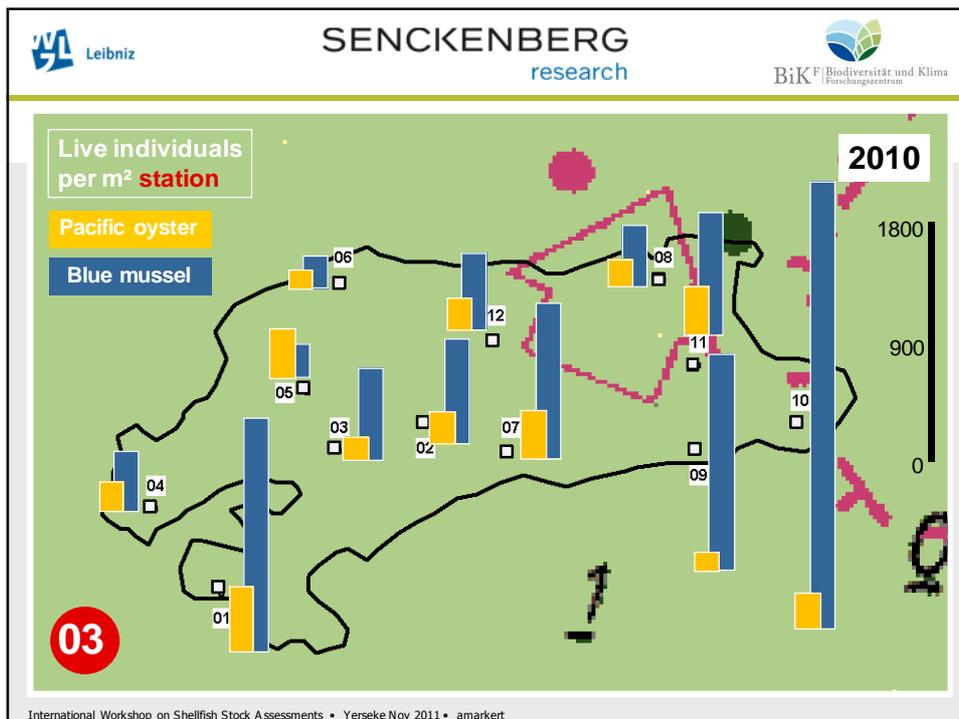
Total (live) wet weight (g)

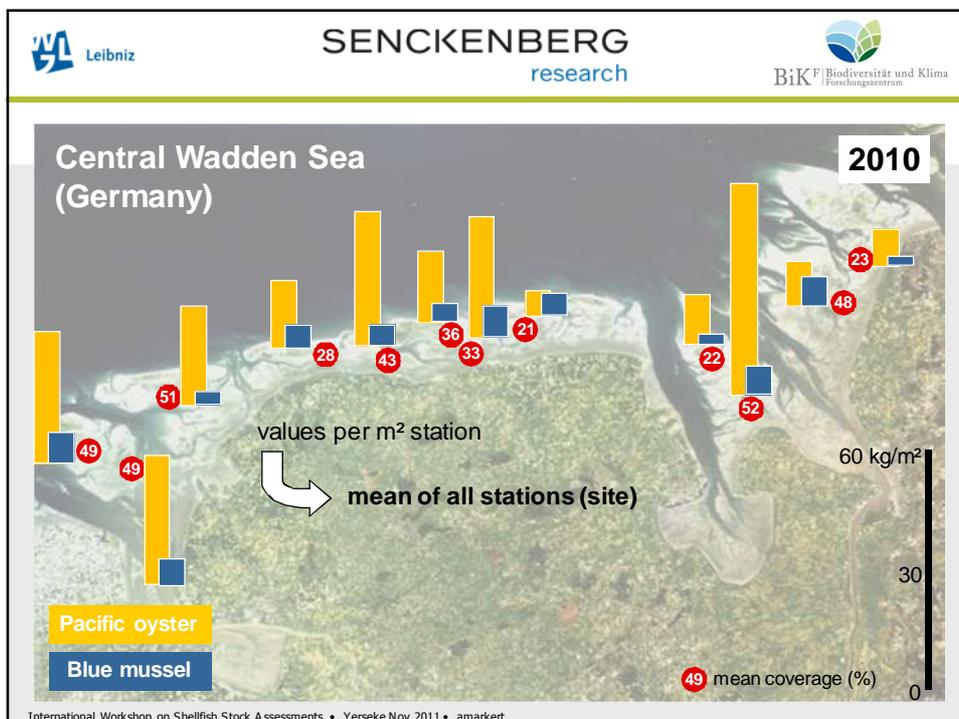
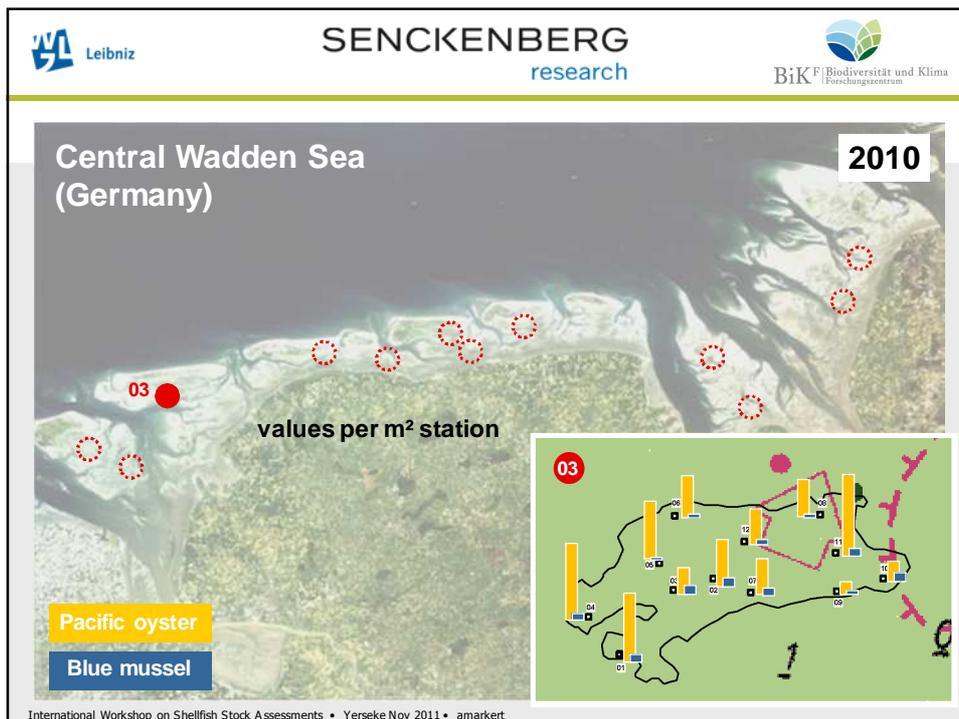
Weight of cocked flesh (g)

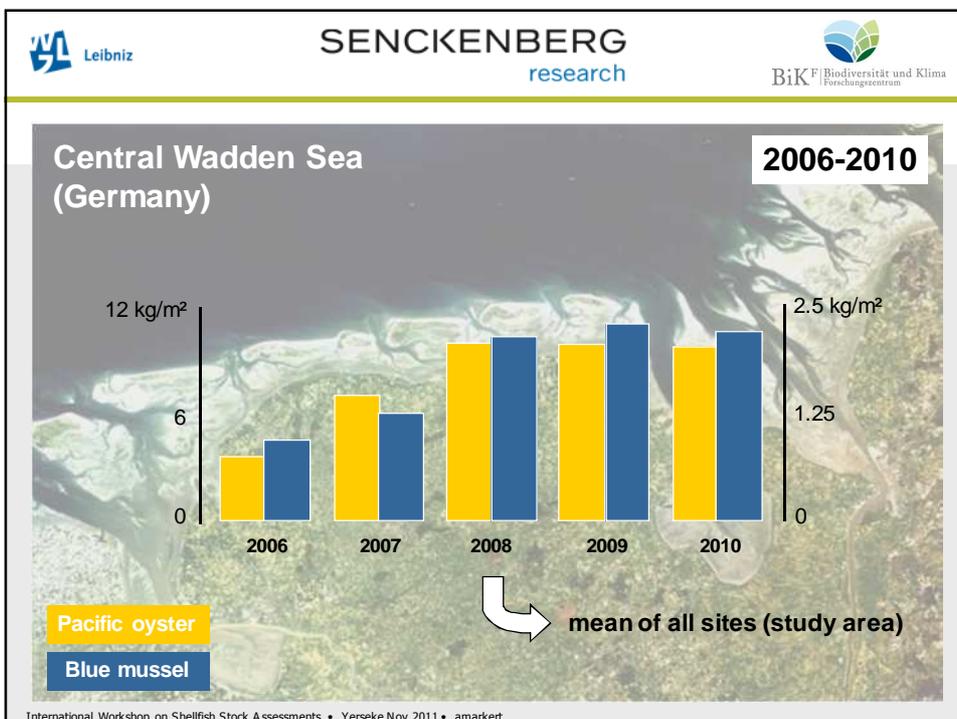
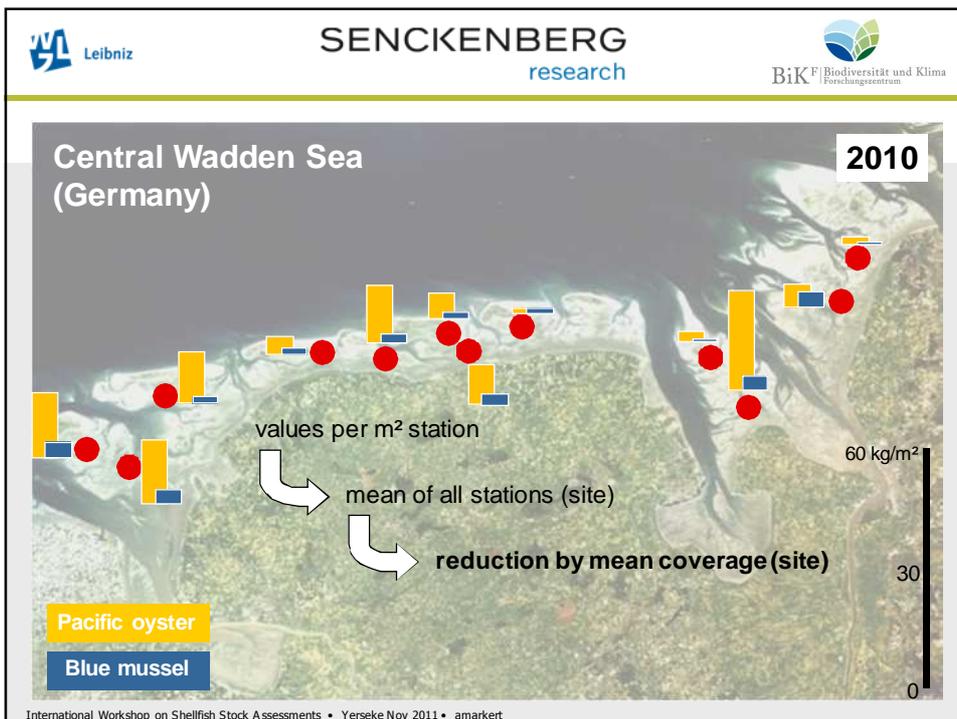
Shell weight (g)

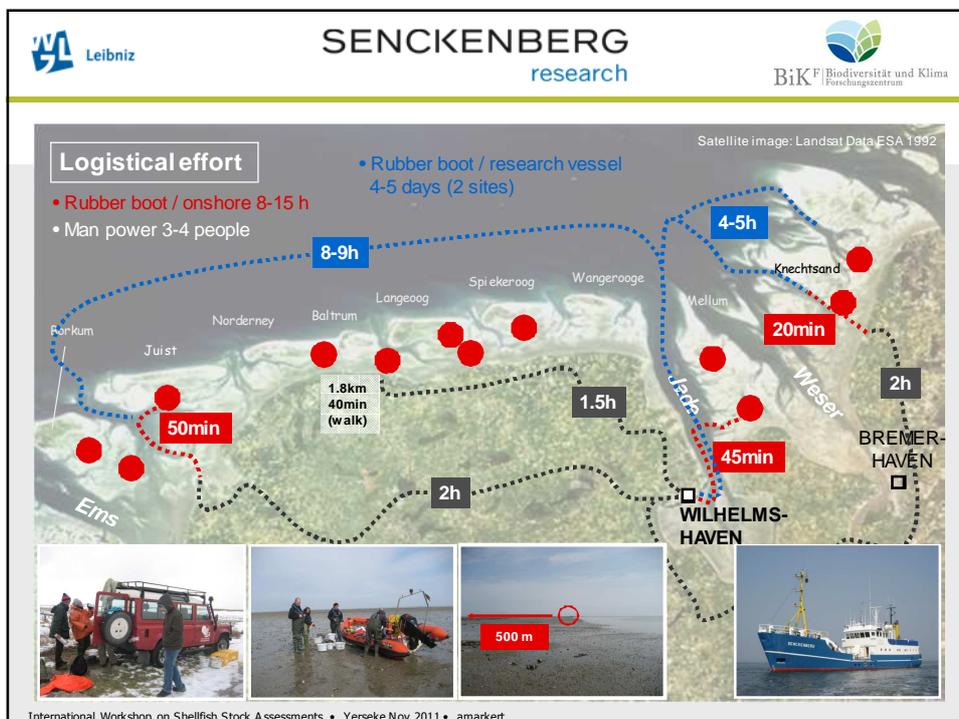
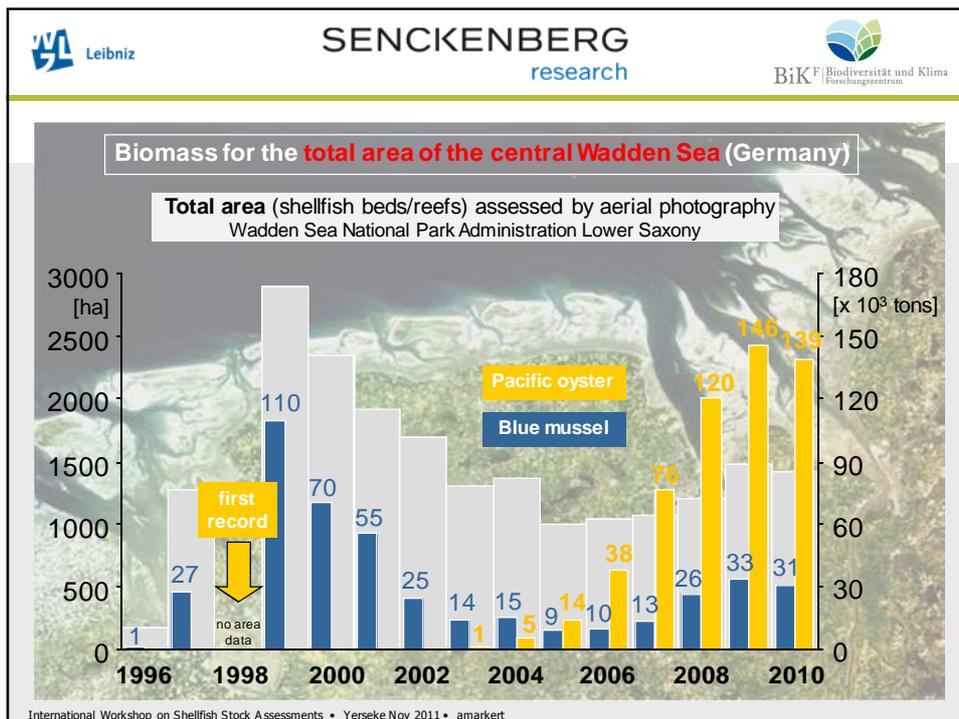
conversion factor
length-weight

International Workshop on Shellfish Stock Assessments • Yerseke Nov 2011 • amarkert











SENCKENBERG

research



Sample processing effort

- rinsing samples (0.5 mm) and sorting species
1 day
- measuring Pacific oysters and blue mussels
2 days
- quantifying biomass Pacific oysters and blue mussels (shell length, live wet weight)
- quantifying biomass Pacific oysters and blue mussels (weight of cooked flesh, shell weight)
2 days

Total effort:
6 days (1.2 weeks)/site
15 weeks (3.75 month)/area

- low tides ± 2 weeks
- weather conditions

5-6 month data assessment





International Workshop on Shellfish Stock Assessments • Yerseke Nov 2011 • amarkert



SENCKENBERG

research



Very special thanks to

(in)numerous field work assistants

and the one and only
Torsten Janßen



Jan-Peter
Carsten
Hasko
Laura
Marieke
Jannik
Anna
Anne
Alex
Hanna
Markus
Sam
Anna
Owen
Jannik
David
Daniel
Boris
Lutz
Wolke
Jasmin
Sven
Thobias
Julias
Bandra
Hanna
Sören
Julia
Franciska
Maja
Maria
Sara
Comelia
and others...



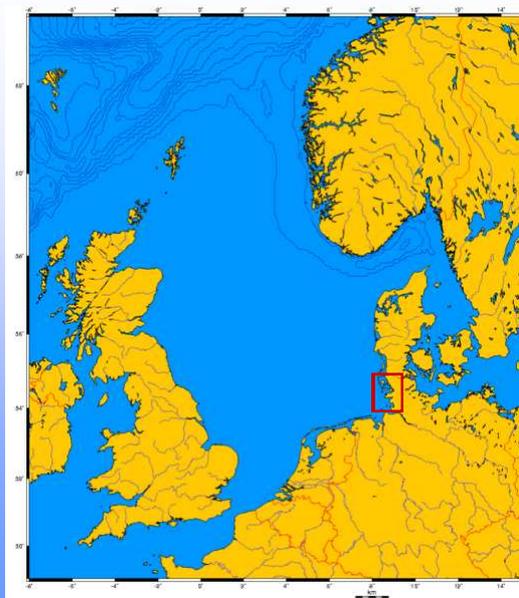
International Workshop on Shellfish Stock Assessments • Yerseke Nov 2011 • amarkert

Heike Büttger

Stock assessment of blue mussels and Pacific oysters in the German Wadden Sea



Nationalpark of the
Wadden Sea
Schleswig-Holstein



<http://de.wikipedia.org>



In the Wadden Sea Plan (1997):

a specific trilateral Target was formulated

aiming for
an increase of the total area
and a more natural development and distribution
of natural intertidal mussel beds,
providing a framework for habitat management.

- comprehensive survey of mussel bed dynamics

Blue mussel monitoring

Denmark

The Netherlands

Germany

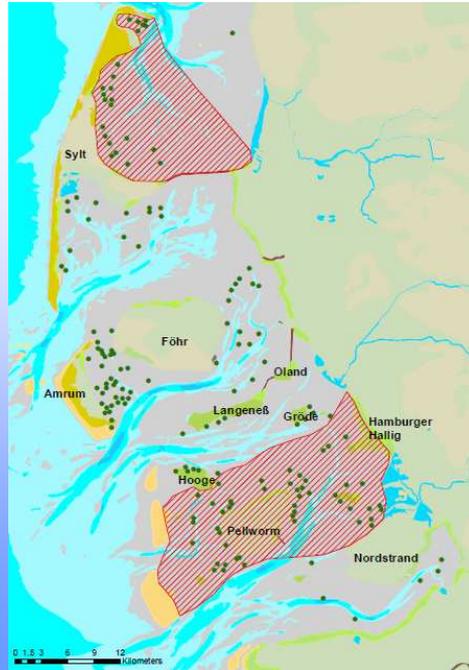
mussel bed sites and sampling areas

200 mussel bed sites

82 populated sites (2009)

two intertidal areas which are surveyed twice a year
(~ 30-35 mussel beds,
~ 50-60 field surveys)

subtidal mussels



Sampling sites in Lower Saxony

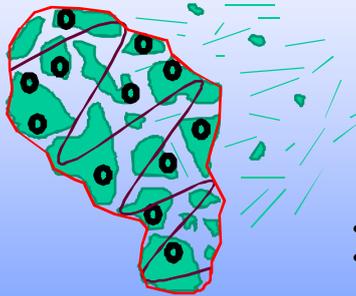


G. Millat



field work

sampling



GPS



- contour
- coverage:
Stiefelmethode



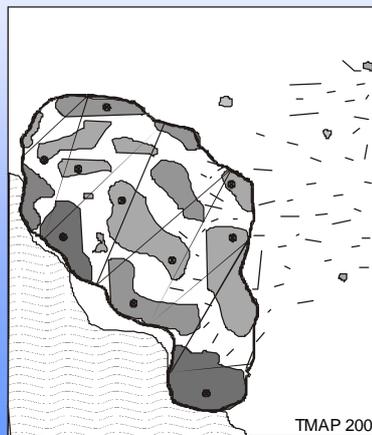
Schleswig-Holstein
coverage

Lower Saxony

coverage
+
proportion ("Besatz"):
defined as percentage
of the patches occupied
by mussels

parameters

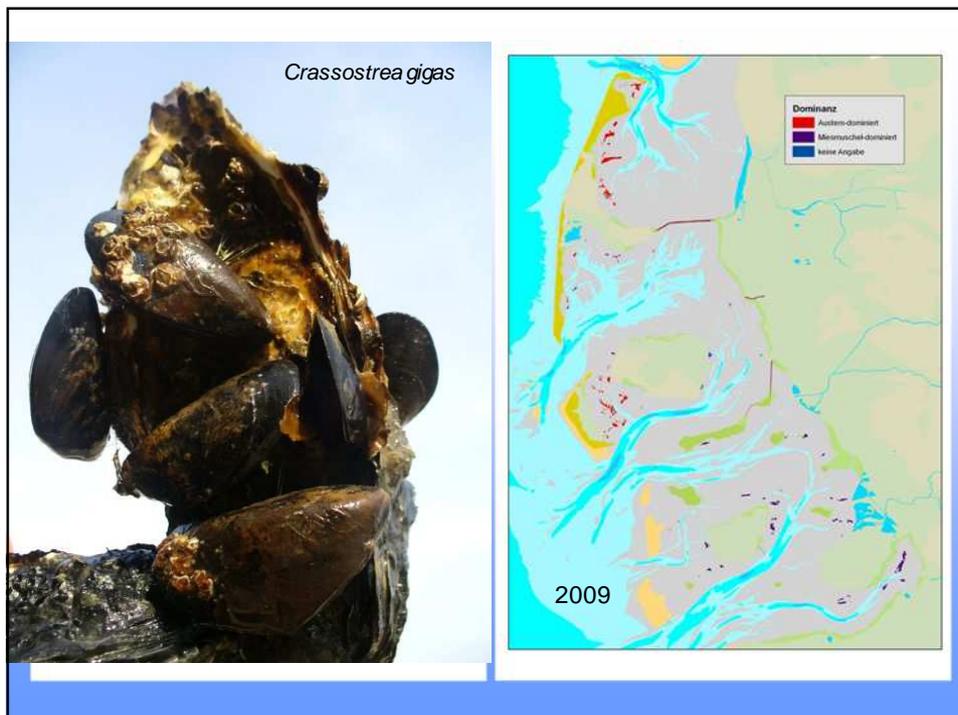
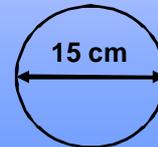
parameter	method
position, size	GPS, field inspection
area	GPS, aerial surveys
coverage	„Stiefelmethode“
algae coverage	estimation
algae biomass	g/m ² (covered amount of heaps)
residual water	% (of total area)
relief, hight	in classes of 10 cm
Shells	few – many
Barnacles	few – many
Sediment	sand - mudd
Densities	numbers/m ²
Length	mm
flesh content	0,01 g (cooked flesh)
shell weight	0,01 g
biomass [g/m ²]	g/m ² (live wet weight)
total biomass [t]	





Sampling
Blue mussel
beds

12 samples





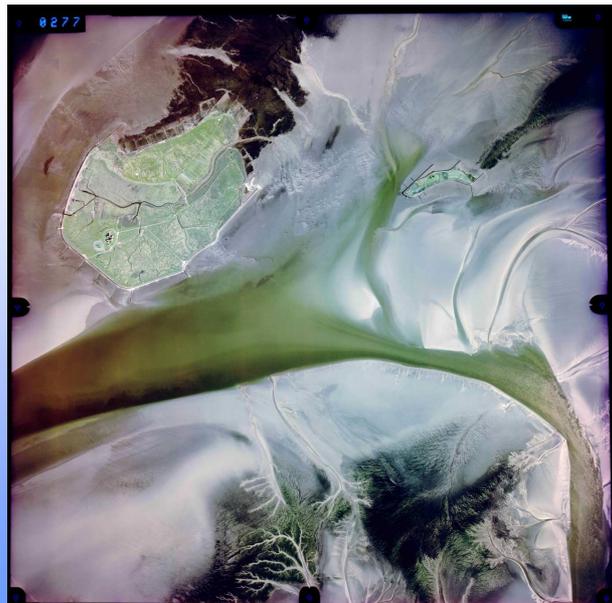
**Sampling
oysters beds**

12 samples

25 x 25 cm

**aerial
photographs**

1 : 25 000
Height 3.8 km



2005
Gröde and Habel

limitations in aerial surveys



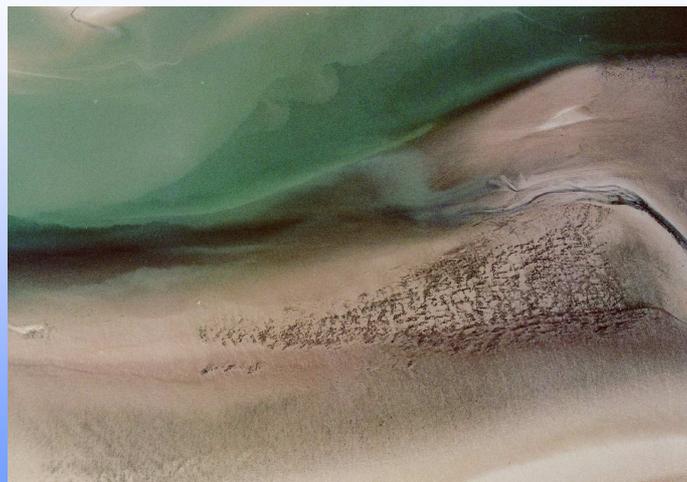
limitations in aerial surveys



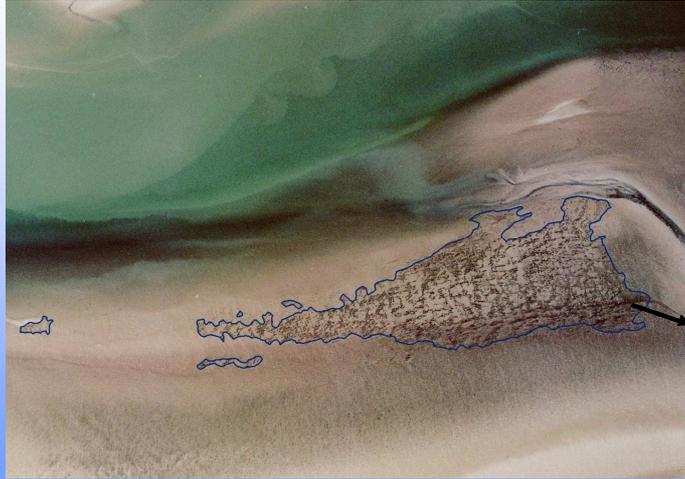
limitations in aerial surveys



limitations in aerial surveys

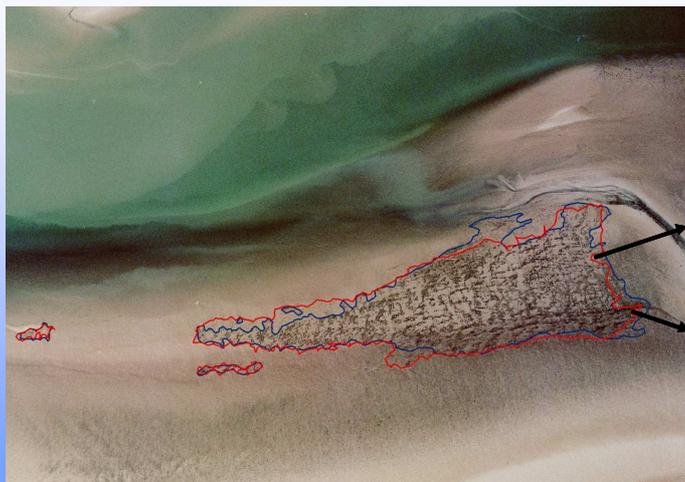


limitations in aerial surveys



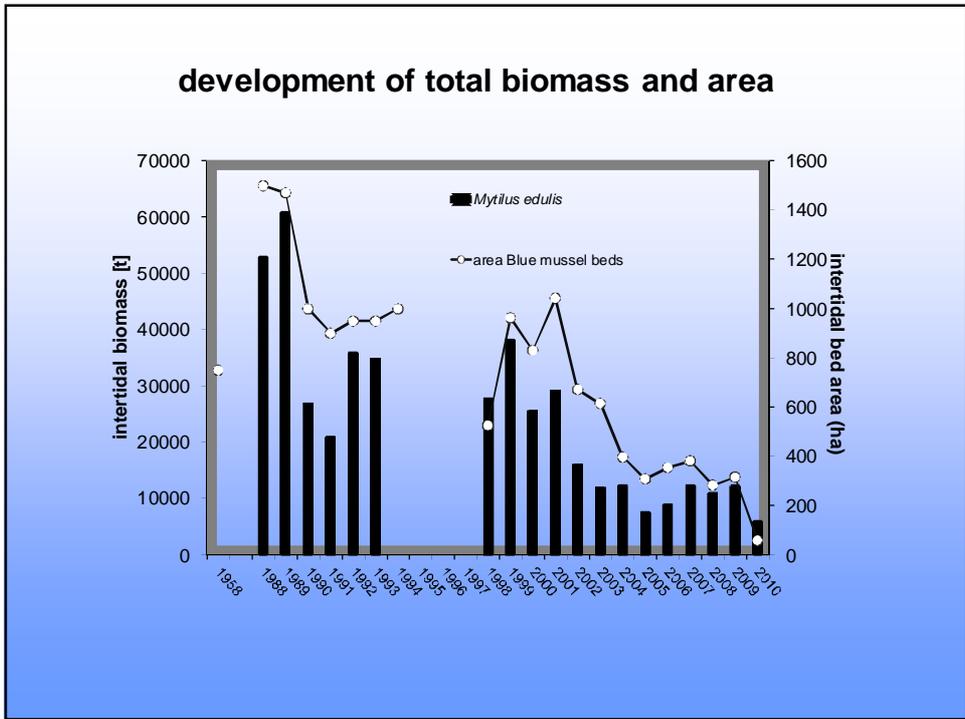
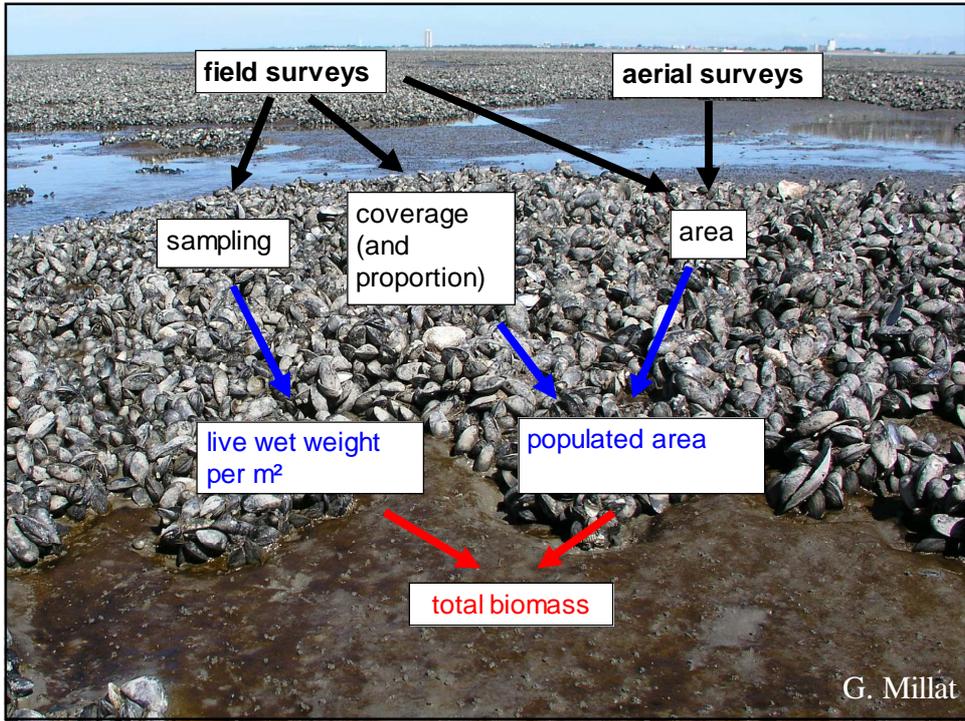
photo

limitations in aerial surveys

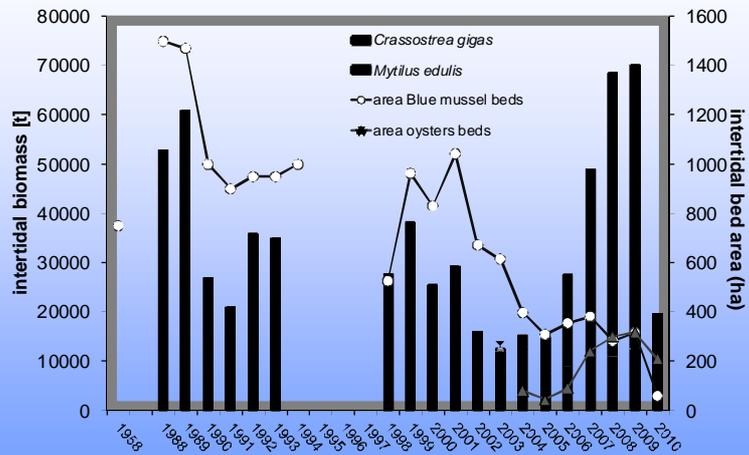


GPS

photo



development of total biomass and area

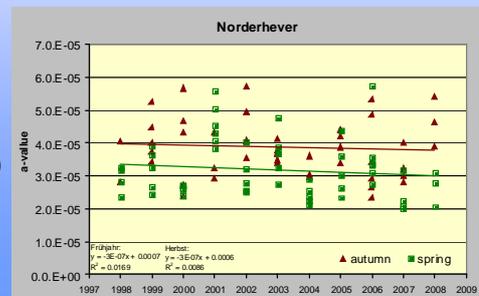
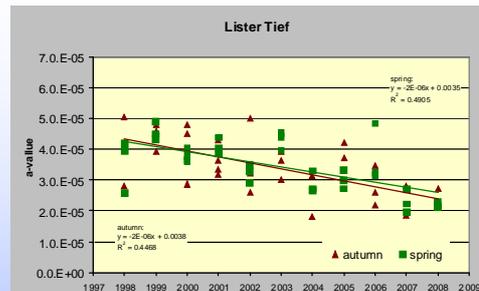


condition of mussels



- sub-sample of each mussel bed
- cooking for flesh content
 - length [mm]
 - flesh weight [g]
 - shell weight [g]
- program MUSSEL (Brinkman 1993)
- basing on

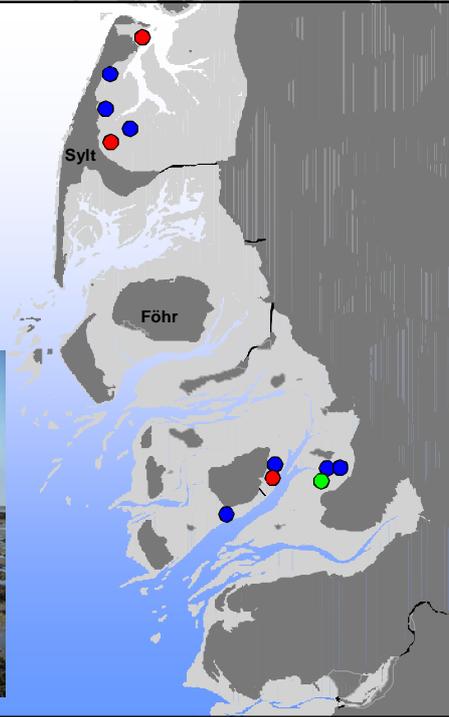
$$W_F = a \cdot L^b \quad (b = 2.8)$$
- a-value



monitoring of the associated macrozoobenthic community

● 1999 – 2002 10 mussel beds
10 samples

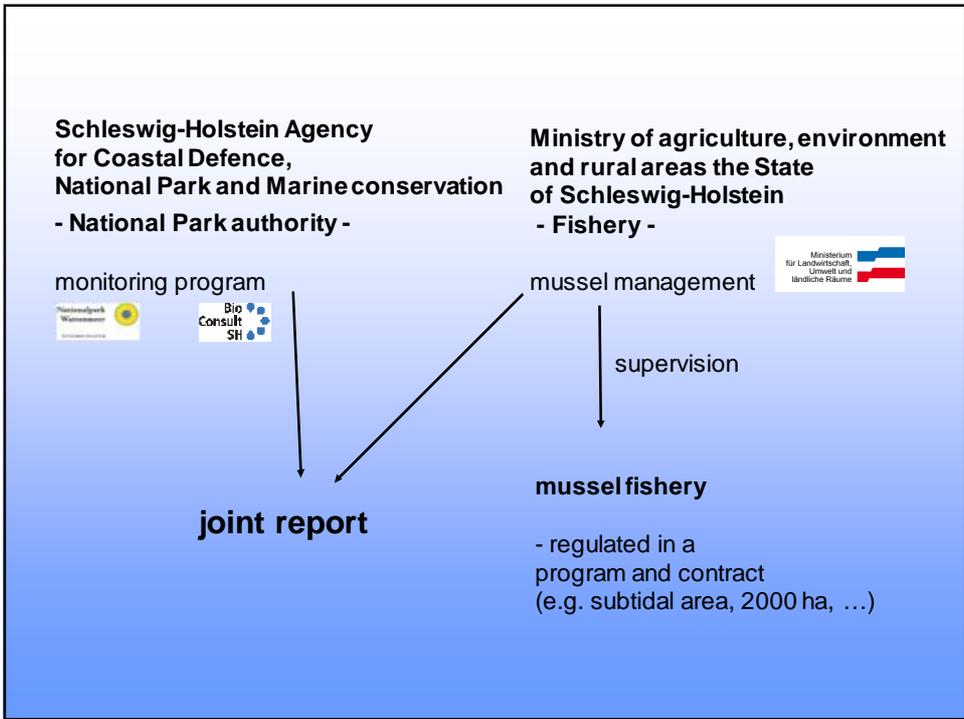
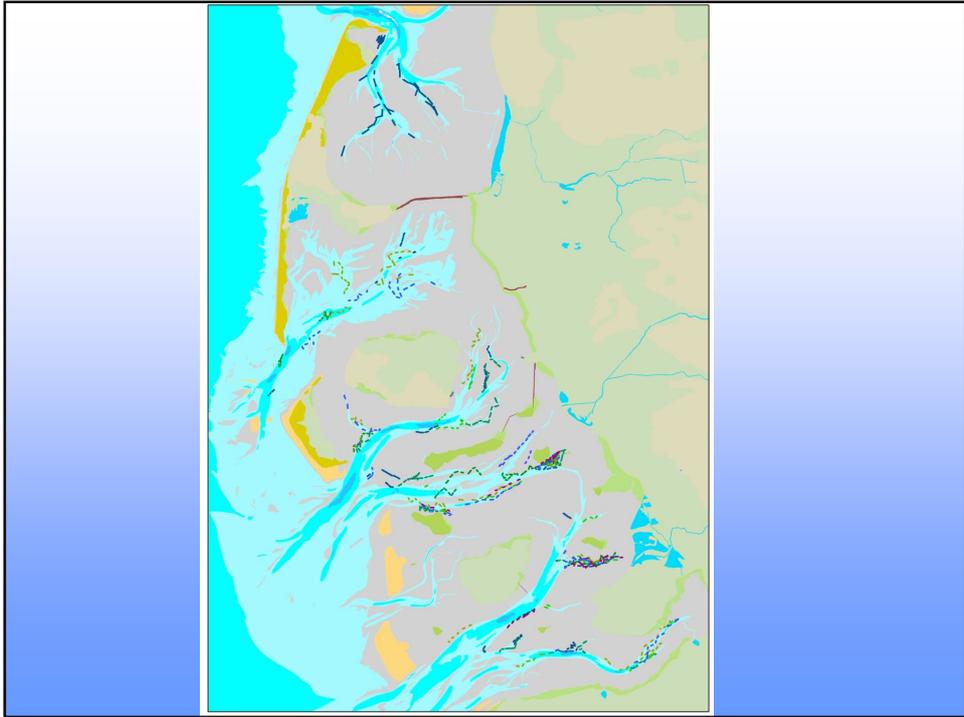
● since 2003 four mussel beds
● 25 samples

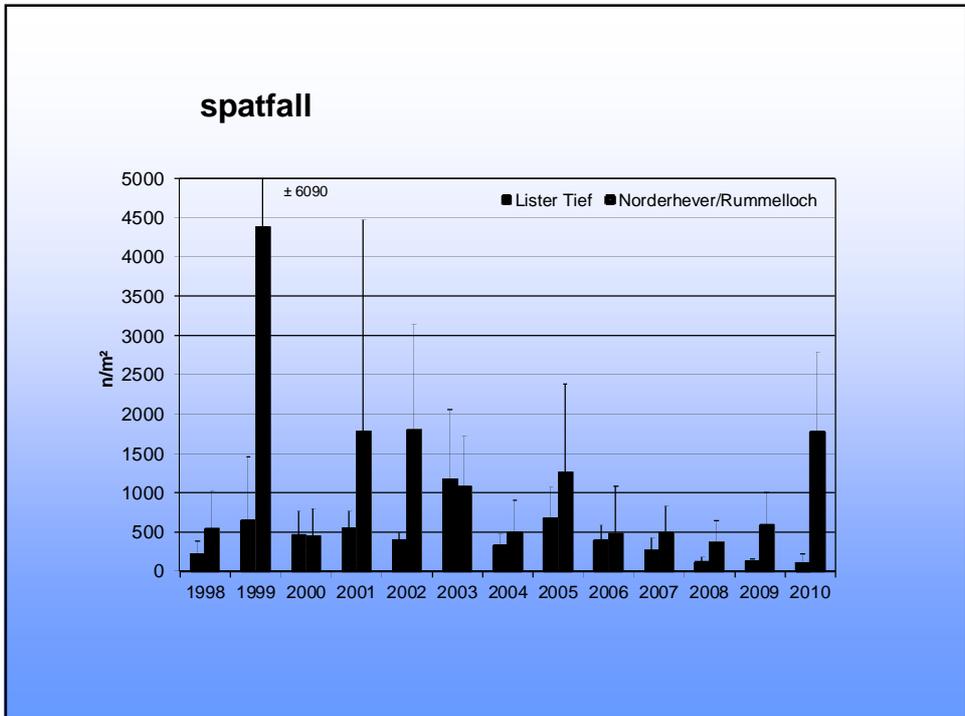


subtidal surveys



- dredging (70 cm)
- approx. 1 kn
- 5 min
- waypoints





sample treatment

- samples are washed through a sieve (1 mm mesh size)
- sample storage in formol (8% solution)
- determination is done by Rendsburger Werkstätten

- species
- number of individuals
- dry weight
- ash free dry weight



Sample proceeding

counting and length measurements

On the biology of reef forming (and other) species and what we should measure in addition to the typical density, length and weight data

Roger Mann

Virginia Institute of Marine Science

Gloucester Point, VA 23062 USA

rmann@vims.edu

http://www.vims.edu/research/units/labgroups/molluscan_ecology/index.php

Outline of the talk

- Stock assessment is driven by models developed for finfish – but unlike finfish reef forming shellfish devote a significant component of natural mortality to creating their own Essential Fish Habitat through shell addition to the benthos.
- So in managing oysters we need to consider how large this component of mortality is and what processes are supported by shell addition.
- This is not just about oyster habitat. It is about biogenic carbonate production and loss, associated chemistry in the near surface sediments, and an optimal environment for infaunal species as well, especially early life history stages.
- We must pose the question “how do we add “shell budgets” to current management practices?” I provide an example from the Virginia oyster fishery
- Some thoughts on other species and locations.

Journal of Shellfish Research, Vol. 26, No. 4, 905-917, 2007.

WHY OYSTER RESTORATION GOALS IN THE CHESAPEAKE BAY ARE NOT AND PROBABLY CANNOT BE ACHIEVED

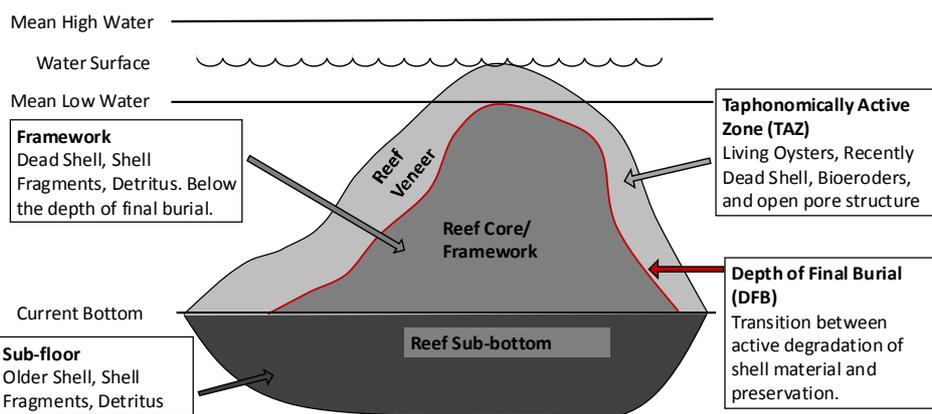
ROGER MANN^{1*} AND ERIC N. POWELL²

¹Virginia Institute of Marine Science, Gloucester Point, Virginia 23062; ²Haskin Shellfish Research Laboratory, Rutgers University, 6959 Miller Avenue, Port Norris, New Jersey 08349

A plea for an evaluation of the needs of oysters in terms of both biological management and habitat sustainability. The reality is that, for this system:

- (a) Shell loss rates in dense populations can be high even when observed $dN/dt \approx 0$ over extended periods.
- (b) Shell loss continues unabated independent of any changes in recruitment and mortality.
- (c) BOTH SUSTAINED RECRUITMENT AND SURVIVAL to greater age are required for accretion. Truncation of age structure exacerbates the problem.
- (d) The absence of BOTH RECRUITMENT AND SURVIVAL leads to net substrate loss, eventual recruitment failure and loss of population.

Structure of an oyster reef: what is happening to the shell carbonate?



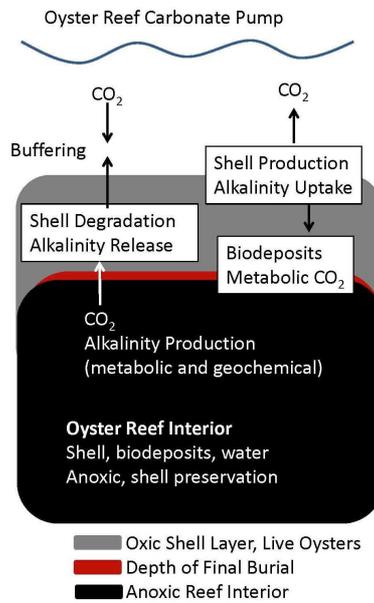
(Graphic from Waldebusser, Powell and Mann, in preparation)

Pleistocene reef, Piankatank River, Virginia



07/28/2009

So what is the underlying structure of the *C. gigas* reefs in the Oosterschelde?



(Graphic from Waldebusser, Powell and Mann, in preparation)



“If you build it they will come.” Kevin Costner, Field of Dreams.
The current, short term approach to shell/carbonate management.



Estimating mortality and contribution to shell base volume

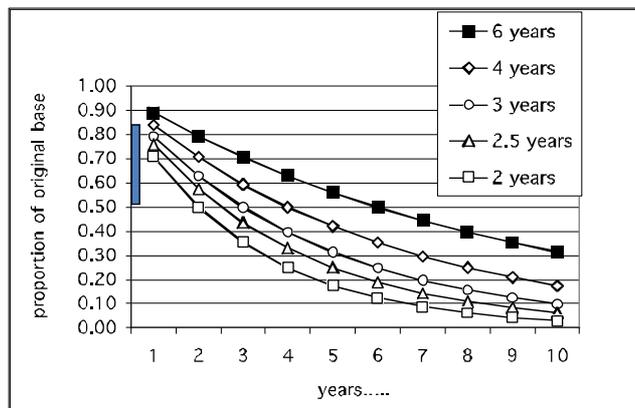
age	n	mortality	1999 year class - serial contribution (L) to the shell base		shell total		year added to shell base
			shell individual	shell total	low	high	
0.33	166.8						
1.33	108.7	58.2	0.02	0.06	1.25	3.32	2000
2.33	49.2	59.4	0.06	0.11	3.40	6.64	2001
3.33	4.5	44.7	0.11	0.19	5.00	8.33	2002
4.33	0.2	4.4	0.19	0.28	0.82	1.23	2003

Now do this for a number of successive year classes - in units of L of shell

age	1999	2000	2001	2002	2003	2004	2005	2006
1,33	0.5	1.2	1.1	2.5	10.4	5.5	0.2	-1.0
2,33	3.5	1.1	3.4	5.7	2.0	1.3	3.3	4.3
3,33	5.6	2.7	3.0	5.0	1.5	0.1	1.9	5.9
4,33	1.8	1.2	1.7	1.8	0.8	0.2	1.0	1.5
low estimate total	11.4	6.1	9.2	15.0	14.7	7.4	6.4	10.6
1,33	1.3	3.3	3.0	6.6	27.9	14.6	0.4	-2.8
2,33	6.8	2.1	6.6	11.1	4.0	2.6	6.5	8.3
3,33	9.4	4.4	5.0	8.3	2.4	0.7	3.2	9.8
4,33	2.7	1.7	2.6	2.8	1.2	0.3	1.6	2.3
high estimate total	20.2	11.6	17.2	28.8	35.5	18.1	11.6	17.7
observed	24.5	27.6	30.0	32.9	28.9	22.9	26.0	28.0
observed (t-1) + low	34.1	30.6	36.8	45.0	47.6	36.3	29.3	36.6
observed (t-1) + high	43.1	36.1	44.8	58.8	68.4	47.0	34.5	43.7
loss (low)	9.6	3.0	6.8	12.1	18.7	13.1	3.3	8.6
loss (high)	18.6	8.5	14.8	25.9	39.5	24.1	8.5	15.7
loss (% low)	28.2	9.9	18.5	26.9	39.3	36.8	11.3	23.5
loss (% high)	43.1	23.6	33.0	44.0	57.7	51.3	24.7	35.9
loss (% med)	35.7	16.8	25.8	35.4	48.5	44.1	18.0	29.7

This is an accounting exercise in fishery management, and can be driven by monitoring

Shell in the TAZ is lost: consider this as an half life rate loss function in a plot of remaining proportion of original shell base versus years. Note the rectangle corresponding to the range of single year loss rates calculated for a stable and productive reef in the James River 2003-2006.



Consider the half life of shell in comparison to life expectancy of the shellfish species

Journal of Shellfish Research, Vol. 29, No. 4, 867–888, 2010.

**MANAGEMENT OF THE PIANKATANK RIVER, VIRGINIA, IN SUPPORT OF OYSTER
(*CRASSOSTREA VIRGINICA*, GMELIN 1791) FISHERY REPLETION**

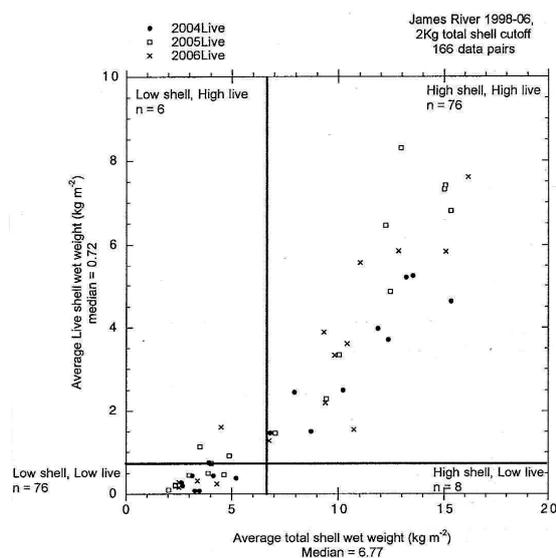
**JULIANA M. HARDING,^{1,*} ROGER MANN,¹ MELISSA J. SOUTHWORTH¹
AND JAMES A. WESSON²**

¹*Department of Fisheries Science, Virginia Institute of Marine Science, College of William and Mary,
Gloucester Point, VA 23062;* ²*Virginia Marine Resources Commission, 2600 Washington Avenue,
Newport News, VA 23607-0756*

ABSTRACT The Piankatank River is a trap-type estuary on the western shore of Chesapeake Bay that has been managed for seed oyster production since 1963. Market oyster production in the river is minimal. Repletion efforts include shell planting and seed removal. We describe sequential changes in population demographics and habitat in relation to repletion activities on eight Piankatank River public oyster reefs from 1998 through 2009. Two reef groups (northern and southern) may be distinguished by density (oysters/m²), biomass (g dry tissue weight), and shell volume (L/m²) data. Age-at-length relationships were estimated from demographic data using a quadratic model. Observed mortality rates were high, and age 3+ oysters were essentially absent. A strong recruitment signal was observed in 1999 and 2002. Between 1998 and 2009, about 30% of the live oysters in the river were harvested as seed, corresponding to ~7.5% of the total shell base in an average year. Typically, for every 5 bushels of shell planted, 1 bushel of seed was harvested (20% return). Even with shell planting (~10 L/m²/y), the river shell budget showed a deficit with respect to the accretion rate required to balance sea level rise and natural degradation processes. During the study period, the mean river recruit-to-stock ratio was ~4. The unusual and consistently high recruit-to-stock ratios suggest that management for modest continuous seed removal may be accomplished without shell planting. Annual stock assessment to identify low recruitment years is recommended as a method to adjust annual seed harvest quotas.

KEY WORDS: Eastern oyster, *Crassostrea virginica*, population demographics, mortality, recruitment, repletion, shell budgets, Piankatank River, Virginia, fishery management

A rotational harvest plan to maximize seed oyster production **and conserve shell**



Transition probabilities after Rothschild & Mullen(1985). *J. de Conseil* 42: 116-124

The shell pool

- Recruitment and growth
 - Live pool: all age classes
 - Dead exposed shell
 - Buried shell, consolidation of reef footprint
-
- Ideal scenario #1 – **All processes and pools in equilibrium with no harvest.** Growth and recruitment contributions match loss to mortality. Dead exposed pool increases with mortality and is balanced against burial.

The shell pool

- **Recruitment and growth**
 - **Live pool: all age classes**
 - Dead exposed shell
 - Buried shell, consolidation of reef footprint
-
- Scenario #2 – **Modest live harvest.** Recruitment and growth processes can support **surplus live production** and harvest while leaving sufficient transfer to dead exposed pool to maintain recruitment and loss to burial.

The shell pool

- **Recruitment and growth**
 - **Live pool: all age classes**
 - **Dead exposed shell**
 - **Buried shell, consolidation of reef footprint**
-
- Scenario #3 – **Reduction in recruitment** cascades throughout and the quantities in each of the pools declines. If the reduction is sustained the system eventually fails.

The shell pool

- Recruitment and growth
 - **Live pool: all age classes**
 - **Dead exposed shell**
 - **Buried shell, consolidation of reef footprint**
-
- Scenario #4 – **Truncation of age live pool age class structure** reduces input to dead and buried pools, even in the face of sustained recruitment and growth. If loss to truncation exceeds surplus production as for scenario #2 the system eventually fails.

The shell pool

- **Recruitment and growth**
 - **Live pool: all age classes**
 - **Dead exposed shell**
 - **Buried shell, consolidation of reef footprint**
-
- Scenario #5 – **Truncation of live pool age class structure** reduces input to dead and buried pools, and reduces recruitment through a S/R relationship (negative feedback loop). If loss to truncation exceeds surplus production as for scenario #2, the system eventually fails.

The shell pool

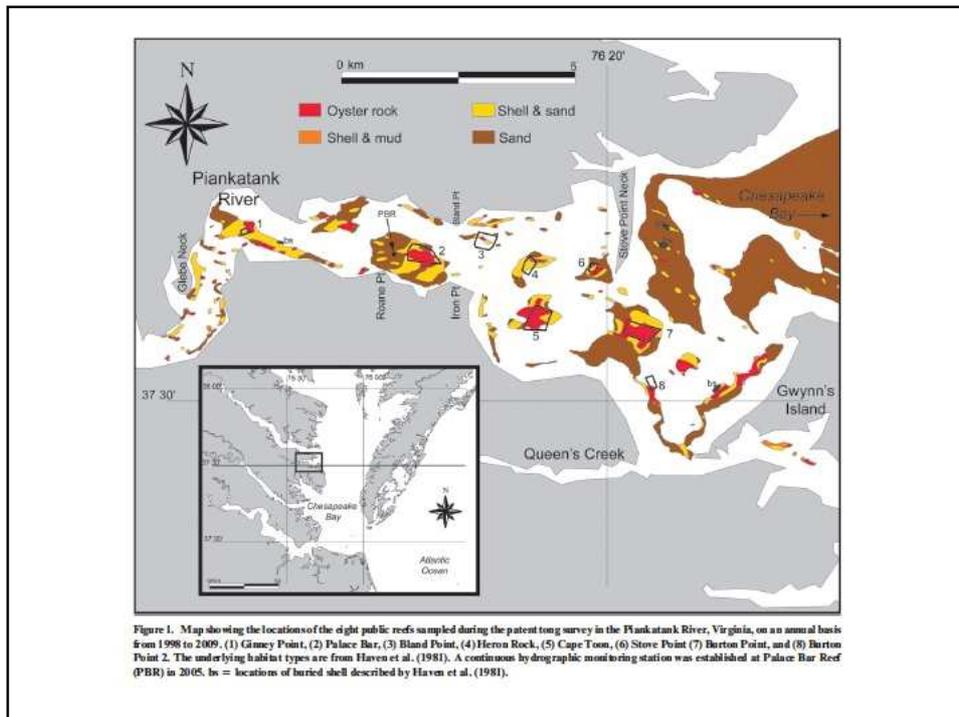
- **Recruitment and growth**
 - **Live pool: all age classes**
 - **Dead exposed shell**
 - **Buried shell, consolidation of reef footprint**
-
- Scenario #6 – **Supplement dead exposed shell to increase recruitment** (assuming substrate is limiting), cascading and sustained impact throughout system if the result is sufficient increase in pool sizes to attain scenario #1. If not then shell addition is required periodically.

The shell pool

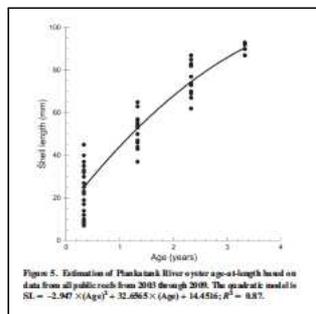
- **Recruitment and growth**
 - **Live pool: all age classes**
 - **Dead exposed shell**
 - Buried shell, consolidation of reef footprint
-
- Scenario #7 - **Supplement dead exposed shell to increase recruitment** (assuming substrate is limiting), **and remove live pool (seed) and remove dead shell with the seed.** Continual manipulation confounds stability of any of the live, dead and/or buried shell pools, equilibrium not sustained, shell addition is required periodically.

The shell pool

- **Recruitment and growth**
 - **Live pool: all age classes**
 - Dead exposed shell
 - Buried shell, consolidation of reef footprint
-
- Scenario #8 – (the question herein) **Can we develop a surplus production option for seed** (analogous to scenario #2) that maintains a shell base with low or no regular shell addition? This requires unusually high and sustained recruitment where age truncation occurs. Are there such options? Tentative yes.



Piankatank River 1998-2009 shell planting (shade), seed harvest (+) and R/S ratio.												
reef #	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
1			+	+		+						
2			+	+		+					+	+
3			+	+		+					+	+
4			+	+		+					+	+
5			+	+		+					+	+
6			+	+		+					+	+
7			+	+		+						
8												
R/S		5.96	3.69	1.48	7.15	1.84	0.18	0.32	17.76	3.22	1.79	0.71



If we know (a) shell added, (b) shell and seed removed, (c) age demographic of population, (d) biomass and per individual shell weight with age, can we estimate a shell pool budget with recruitment, growth, live oyster, dead exposed shell, and buried shell components? Yes. We have this for multiple successive years of manipulation with data on the RECRUIT/STOCK (R/S) ratio. Can we make a predictive model for a fixed R/S and harvest options? Yes.

Model options				
Assume initial seed density of 150/m ² and a continuing R/S of 4.0				
Mortality profiles as cumulative values				
Seed harvest is a proportion of all oysters present				
transition	A	B	C	D
YOY-Age1	0.5	0.7	0.75	0.85
Age 1-2	0.75	0.85	0.88	0.9
Age 2-3	0.95	0.95	0.95	0.95
Age 3-4	1	1	1	1

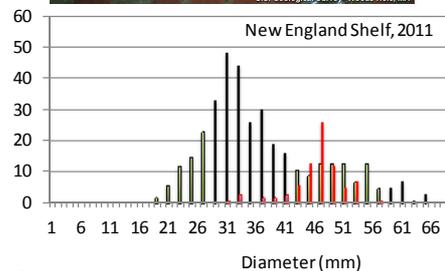
There are rarely 4 year old animals in this river system.
 Are the model options sensitive to cumulative mortality rates?
 Base the utility of the option on the ability to sustain a shell base.
 Litmus tests use shell accretion of 4.55 and 6.5 L/m² /y (high?)
 What do the analyses look like?

	YEAR	1	2	3	4	5	6	7	8	9	10
A: 0.7/Y HARVEST	YOY	150	480	115	312	142	208	133	148	112	110
	TOTAL	270	576	375	430	315	319	257	241	204	185
	HARVEST	0	0.7								
	SHELL		11.4	17.4	30.6	27.7	21.1	21.4	17.1	16.2	13.6
B: 0.5/Y HARVEST	YOY	150	300	106	194	91	127	73	85	55	58
	TOTAL	225	353	203	240	155	163	116	113	84	79
	SHELL		8.6	10.6	13.4	10.2	9.1	7.3	6.4	5.2	4.6
C: 0.15/Y HARVEST	YOY	150	252	146	230	150	212	152	197	152	184
	TOTAL	213	295	214	274	212	257	210	242	206	228
	SHELL		7.8	8.9	10.5	9.5	9.9	9.2	9.5	8.9	9.0
C: ROTATE 0.7/Y	YOY	150	252.0	51.0	271.0	25.0	279.0	17.0	283.0	15.0	287.0
	TOTAL	213	295.0	118.7	292.0	95.0	293.0	88.0	296.0	87.0	304.0
	HARVEST	0	0.7	0.0	0.7	0.0	0.7	0.0	0.7	0.0	0.7
	SHELL		7.8	8.9	9.4	7.3	8.6	6.8	8.5	6.7	8.5
D: NO HARVEST	YOY	150	180	102	117	72	77	51	51	35	34
	TOTAL	195	206	131	135	91	90	64	60	43	40
	SHELL		6.7	5.9	5.3	4.3	3.6	2.9	2.4	2.0	1.6

Model options - <u>conclusions</u>				
Assume initial seed density of 150/m ² and a continuing R/S of 4.0				
Mortality profiles as cumulative values				
Seed harvest is a proportion of all oysters present				
transition	A	B	C	D
YOY-Age1	0.5	0.7	0.75	0.85
Age 1-2	0.75	0.85	0.88	0.9
Age 2-3	0.95	0.95	0.95	0.95
Age 3-4	1	1	1	1

- The model options are very sensitive to cumulative mortality rates
- The 10 year projection of the shell base appears to be useful projection.
- Litmus tests using shell accretion of 4.55 and 6.5 L/m² /y are exceeded by several of the harvest scenarios and can be matched to mortality rates.
- The rotational approach, harvesting every other year with profile C, appears tractable to maintain high harvest (0.7) with stability of shell base.
- These projections are not difficult to examine and offer reasonable management options that should be investigated.

It is not just about oysters, consider echinoderms can play a similar role on coastal shelf systems: Common Sand Dollar *Echinarachnius parma*.

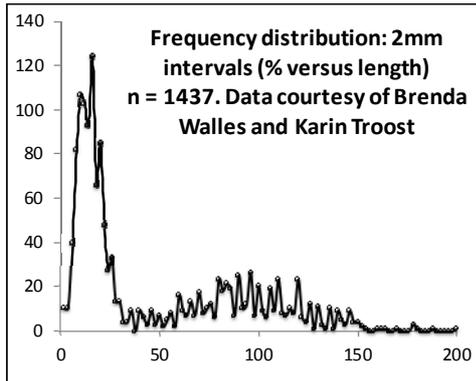


Questions:

1. Can we estimate absolute abundance?
2. Can we build a growth and mortality model?
3. Can we estimate carbonate budgets?

With thanks to Dave Rudders, Bill DuPaul, Captain Charlie Quinn and crew of the F/V Celtic.

So what is the underlying structure of the *C. gigas* reefs in the Oesterschelde?



With recognition of Brenda Walles and Karin Troost: I pose questions.
 Can we go from frequency to:
 Age distribution?
 Mortality?
 Shell to the underlying reef?
 Is it accreting?
 What is the filtration rate per m²?
 How does this contribute to accretion?
 Stabilization of habitat in an eroding environment?
 Is this an explanation of mechanism of invasion?



Fishing for the surf clam *Spisula solidissima*, Mid Atlantic Shelf, August 2011

Carbonates: it's not just about oysters, its about estuaries, coastal and shelf systems world wide.

With thanks to Karin Troost and Brenda Walles for data, and to IMARES for hosting this meeting.

QUESTIONS?



Sunrise, New England Shelf, August 2011

New survey techniques

Introduction and state of the art at IMARES

Johan Craeymeersch



New survey techniques

- New sampling devices (semi-grab / Ensis dredge)



- Improving sampling design (stratification)

- traditionally :
 - Input from fishermen, data of preceding years
- more and more: no info → alternative methods ?
 - Habitat suitability models ?
 - Acoustic signatures of shellfish beds ?

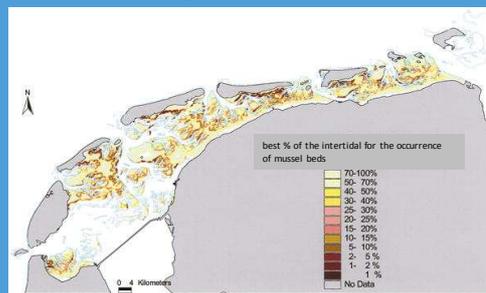
Habitat suitability models

Models statistically relate the geographic distribution of the species to their environment by estimating the effects of (biotic and) abiotic factors

= ecological niche modelling

- Probably very efficient approach for species with rather narrow niche
 - e.g. *Mytilus edulis*

Brinkman, A.G., Dankers, N., van Stralen, M., 2002. An analysis of mussel bed habitats in the Dutch Wadden Sea. Helgolander marine research 56, 59-75.

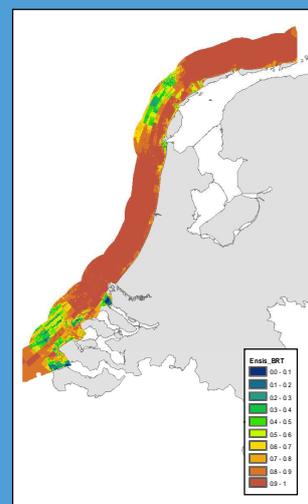


Habitat suitability models

- Not efficient approach for species with broad niche
 - e.g. *Ensis directus*

HSM (BRT) for presence

De Meseel, I., Craeymeersch, J., Schellekens, T., van Zweeken, C., Wilsman, J., Leopold, M., Dijkman, E., Cronin, K., 2011. Kansenkaarten voor schelpdieren op basis van abiotiek en hun relatie tot het voorkomen van zwarte zee-eenden. IMARES Wageningen UR, Rapport CD42/11.



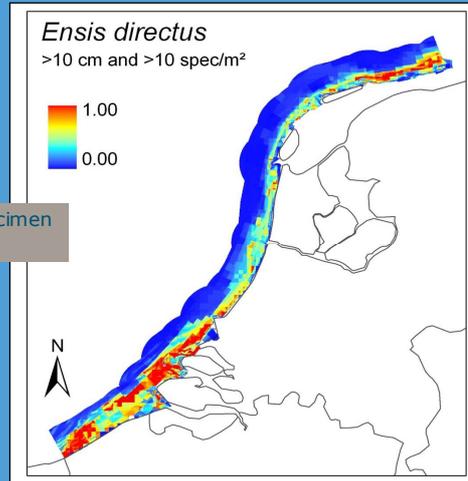
Habitat suitability models

- Not efficient approach for species with broad niche ?
 - e.g. *Ensis directus*

HSM (MaxEnt) for presence of large specimen (>10cm) & high densities (>10ind/m²)

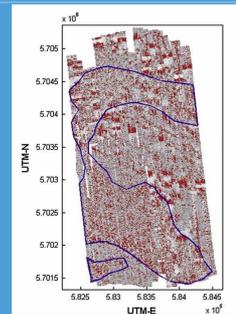
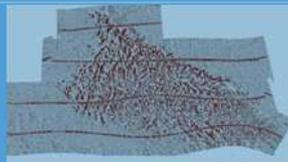
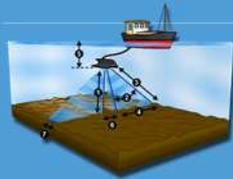
grid cell size needed ?

Houzioux, J.-S., Craeymeersch, J., Merckx, B., Schellekens, T., Kerckhof, F., Van Lancker, V., Courtens, W., Stienen, E.W.M., Breine, N., M., R., Perdon, J., Goudswaard, P.C., Van Hoey, G., Rumes, B., Hostens, K., Vindck, M., Degraer, S., in press. Ecosystem sensitivity to invasive species, EnSiS. Final report.



Acoustic surveys

1. side scan sonar



- Full-cover imaging of large surface at high resolution (cost-effective)
- Often clear acoustic signatures for epibenthic species (mussels, oysters), not for endobenthic species (through shells)
- More commonly: nature of zones of high backscattering uncertain
 - → requiring supplementary sampling (calibration, validation)
 - → need for improved pattern recognition techniques (identification less ambiguously; thresholds of highlighting at present by trial-and-error)



van Overmeeren, R., Craeymeersch, J., van Dalßen, J., Fey, F., van Heteren, S., Meesters, H.W.G., 2009. Acoustic habitat and shellfish mapping and monitoring in shallow coastal water - side scan sonar experiences in the Netherlands. Estuarine, Coastal and Shelf Science 84, 437-448.

Mesdag, C.S., 2001. Side Scan Sonar opnamen ten behoeve van de inventarisatie van *Spisula*. Nederlands Instituut voor Toegepaste Geowetenschappen TNO, Utrecht, p. 5.

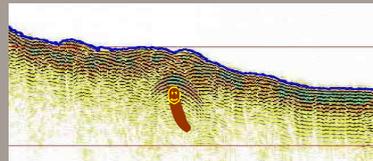
Acoustic surveys 2. echosounder

- Sediment penetrating echosounder (Odom HT100 echosounder, 24 kHz transducer)



No. of transducers	1
Trigger rate	20 pulses / sec
Transducer depth	0.35 m
Heave sensor	offline filtering technique
Data acquisition	SILAS

- April 2005: field surveys in areas indicated by fishermen
- Possible indicator for presence of razor shells: the presence of diffraction hyperbola at depths of >10cm in the sediment



- However: lot of noise (especially at the seabed surface) due to other animals, fisheries, etc.
- June 2007: survey planned on known razor shell bed at lower eulitot



Craeymeersch, J.A., van Stralen, M.R., Wijsman, J.W., Kesteloo, J., Perdon, J., De Mesel, L., 2007. Ontwikkeling van een monstertuig voor bestandsopnames van mesheften. Wageningen IMARES O284/07, 25 pp.

Conclusion

looking forward for better, practical and cost-efficient techniques



An Optimum Allocation Analysis Planning Tool to Support Habitat Mapping and Stock Assessments

James Strong

Agri-Food and Biosciences Institute



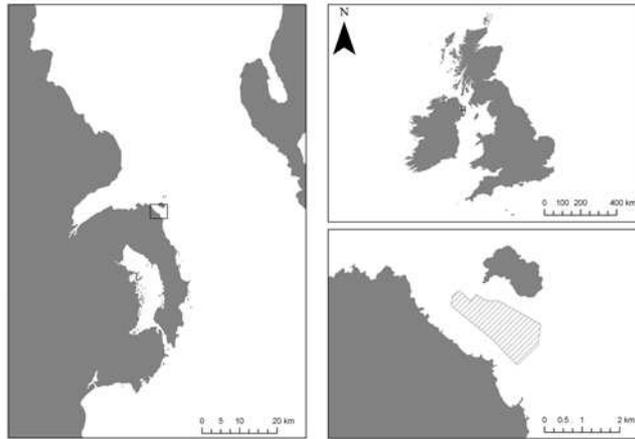
Optimum Allocation Analysis

A procedure used in stratified sampling to:

- allocate numbers of sample units to different strata in order to either maximize precision at a fixed cost or
- minimize cost for a selected level of precision (precision in this sense meaning both closeness to a true value and the repeatability over time).

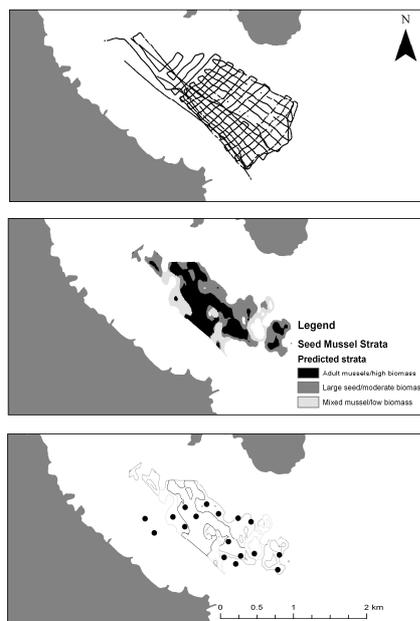


Seed Mussel Stock Assessment Case Study



Spring 2010
seed mussel
survey (*Mytilus
edulis* L.)

Survey site -
Donaghadee
Sound, Northern
Ireland



50 m track spaced RoxAnn survey
collected at 6 knots.

The E1 (roughness), E2
(Hardness) and depth were
standardised, and imported into
SPAA for Two Step Cluster
Analysis to find the appropriate
number of clusters (strata).

The E1 and E2 were then imported
into Surfer for interpolation with
Kriging.

Exported to AcrMap – Isocluster
and Maximum likelihood tools
were used for classified surface
production.



MS Excel OAA Macro

From the zones, the mean and variance are extracted for E1, E2 and depth for insertion into the OAA macro.

Positive correlations between two interactions, and one with no correlation.

Ground truthing scenarios and required ground-truthing replication.

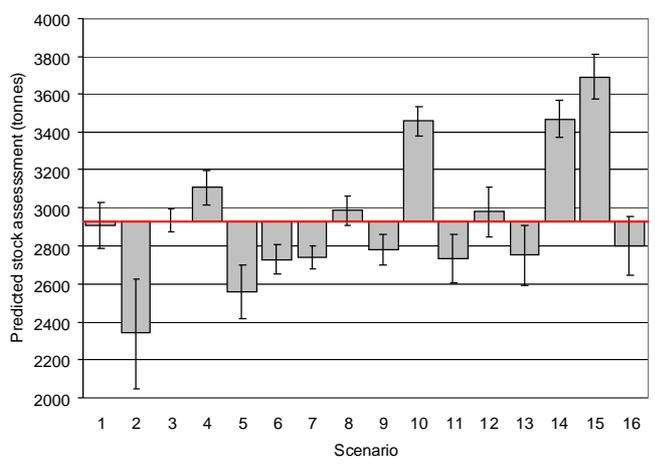
Scenario	Title	Resource Zone			Total
		1	2	3	
1	OAA 6%	3	2	2	7
2	OAA 10%	1	1	1	3
3	All/Area	5	6	3	14
4	Equal 3	3	3	3	9
5	Equal 2	2	2	2	6
6	Random	4	4	3	11
7	Random	5	5	3	13
8	Random	3	5	3	11
9	Random	4	5	2	11
10	Random	5	3	3	11
11	Random	4	1	3	8
12	Random	2	5	1	8
13	Random	1	3	2	6
14	Random	4	6	1	11
15	Random	3	4	1	8
16	Random	2	3	1	6

Each scenario underwent 'Bootstrapping with resampling' 1000 times.

Each Bootstrapping permutation was used in the stock assessment calculations.

The actual amount of seed mussel removed from the site is known (2929 tonnes).





Scenario stock assessment predicted tonnage mode (grey bar) shown as deviation from the 'actual' fished tonnage of seed mussel (2,929 tonnes). Y-axis bars are Standard Error (n = 1000).

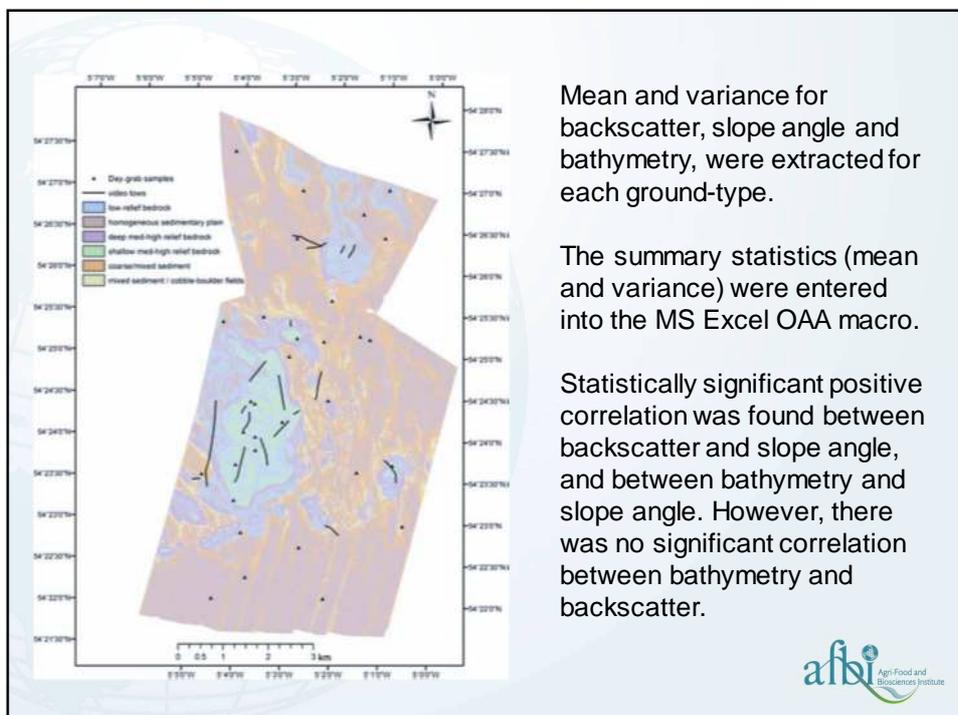
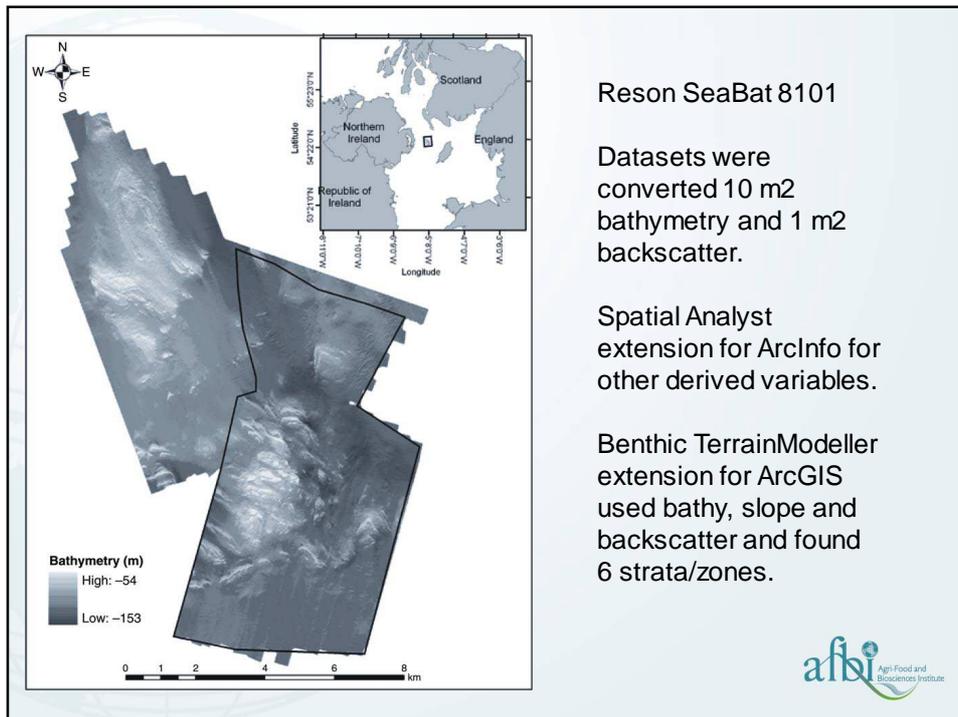


Discussion

This paper has demonstrated the early potential of OAA in objectively establishing the required effort for the ground-truthing of remotely sensed acoustic datasets in benthic mapping.

The OAA incorporates the area for each predicted resource zone and measures of variance within each to efficiently allocate dredges amongst the selected strata. As a result, acoustic resource zones were effectively quantified and generated an accurate stock assessment that closely matched the actual fished tonnage.





Ground truthing

- The coefficient of variation (CV) was set at 5%
- Ground-truthing used both video sledge and Day grab.
- OAA sampling area has been divided: one-fifth to be sampled by grabs, and four-fifths to be sampled by video tows.
- Video footage was analysed every 30 seconds and percentage cover of Wentworth-scale-defined sediments was calculated for each paused image using an overlaid grid.



Results

Zone	Predicted whole grabs (m ²)	Predicted video units (m ²)	Predicted total (m ²)	Actual grabs (m ²)	Actual video (m ²)	Actual total (m ²)
Mixed sediment with boulder or cobble fields	16 (1.60)	26 (6.40)	8.00	5 (0.50)	27 (6.75)	8.00
Homogeneous sedimentary plain	44 (4.40)	70 (17.60)	22.00	11 (1.10)	77 (19.25)	22.00
Deep, medium-high relief bedrock outcrops	18 (1.80)	29 (7.20)	9.00	2 (0.20)	34 (8.50)	9.00
Shallow, medium-high relief bedrock outcrops	6 (0.60)	10 (2.40)	3.00	2 (0.20)	10 (2.50)	3.00
Coarse and/or mixed sediment	28 (2.80)	45 (11.20)	14.00	9 (0.90)	47 (11.75)	14.00
Low relief bedrock	–	12 (3.00)	3.00	–	12 (3.00)	3.00
Total (m ²)	11.20	47.80	59.00	2.90	51.75	54.65

Sampling effort between grabs and video work has been apportioned 1:5, respectively (see Material and methods).

Due to the rocky nature of some of the ground types it wasn't possible to collect all of the required grabs – extra video samples were collected to compensate in these areas.



Results – OAA GT worked backwards

Ground-type	Mean phi			Silt and clay fraction (%)			Broad habitat type (video)		
	n (m ²)	Mean	Variance	n (m ²)	Mean	Variance	n (m ²)	Mean	Variance
1	6 (1.0)	4.55	3.37	6 (1.0)	63.12	519.64	27 (6.75)	1.95	0.59
2	18 (4.4)	5.68	0.78	18 (4.4)	72.60	207.61	77 (19.25)	1.57	0.29
3	7 (1.8)	4.93	0.19	7 (1.8)	63.20	119.82	34 (8.5)	2.01	0.90
4	2 (0.60)	2.79	5.52	2 (0.60)	47.58	123.87	10 (2.5)	2.01	0.88
5	11 (2.8)	5.22	1.36	11 (2.8)	65.75	254.60	47 (11.75)	1.28	0.18
6	–	–	–	–	–	–	12 (3)	1.75	0.81

Ground-truthing parameter	Estimated required sampling for 5% CV	Actual ground-truthing sampling	Estimated CV for actual ground-truthing (%)
Sediment mean phi	21	725	12.30
Sediment silt and clay fraction (%)	21	725	13.41
Video classification	57	5175	5.25

The means and variances from the ground-truthing data were entered into the OAA for the reverse calculation of the actual CV for each parameter.

The CV for video classification was 5.25%. The averaged CV for sediment mean phi and silt/clay fraction were 12.3 and 13.4%, respectively and notably higher than the estimated 5%.



Discussion

- The objective approach to ground-truthing survey strategy using OAA shows merit but needs further development and testing.
- We believe that OAA is useful in seabed-habitat mapping because OAA:
 - uses existing data objectively from a series of predetermined ground-types to stratify ground-truthing effort,
 - aims to maximize the resulting precision of the survey with respect to minimizing effort,
 - allows sampling precision, as defined by the CV, to be set by the user as appropriate,
 - can be applied retrospectively and readily by incorporating actual numbers of samples, such that the statistical precision of historical ground-truthing campaigns can be assessed and confidence assessment for existing maps.



OAA Assumptions for the Planning Tool

The OAA method used here relies on two key relationships:

- (i) that the variance for the acoustic variables is proportional to the observed ground-type diversity, and
- (ii) that the physical variables selected and combined within the OAA broadly correlate with recognizable substratum heterogeneity.



Table 3. Recommended sample sizes (in m²) from OAA based on individual variables for a CV of 5% for each ground-type (zone), and recommended samples sizes using proportional allocation.

Allocation basis	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Sample total	CV using slope angle (%)	CV using backscatter (%)	CV using bathymetry (%)
Slope angle and area	10	16	13	5	15	4	63	5	4	7
Backscatter and area	9	36	9	3	20	4	81	6	5	8
Bathymetry and area	4	14	4	0	7	1	30	3	3	5
Average of above	8	22	9	3	14	3	58	--	--	--
Proportional strata area only	8	26	6	2	14	3	--	--	--	--

Area has the greatest impact on the OAA-predicted ground-truthing units. Variances associated with each ground-type have impacted significantly on the OAA calculations, such that the recommended sampling does differ from proportional allocation based just on area.

It is also evident that the choice of the remotely sensed input variable used to represent ground-type heterogeneity has a significant impact on the resulting distribution of recommended sampling effort.

The weighting of ground-truthing effort recommended by using backscatter and bathymetry is also variable between ground-types.



International Workshop on Shellfish Stock Assessments:
State of the Art and New Techniques. Yerseke, NL, 3-4/11/2011

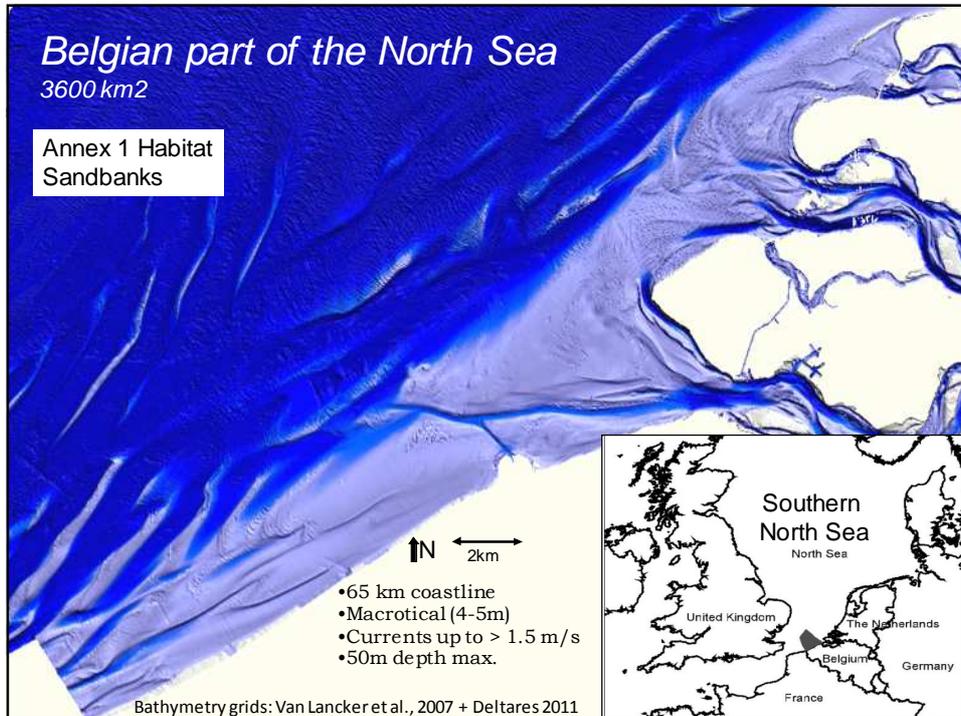
Use of side-scan sonar and multibeam in mapping *shellfish beds* in the North Sea

Vera Van Lancker

Management Unit of the North Sea Mathematical Models
MUMM | BMM | UGMM



EnSIS QUEST4D GeoSeas



Mapping soft substratum biodiversity hotspots

- Importance of ecosystem engineers; when in high densities:
 - Structural effect on their environment
 - Attraction of more species
 - Positive feedback with some fish species
- Their mapping is crucial for ecosystem-based approach to management (link MSFD)

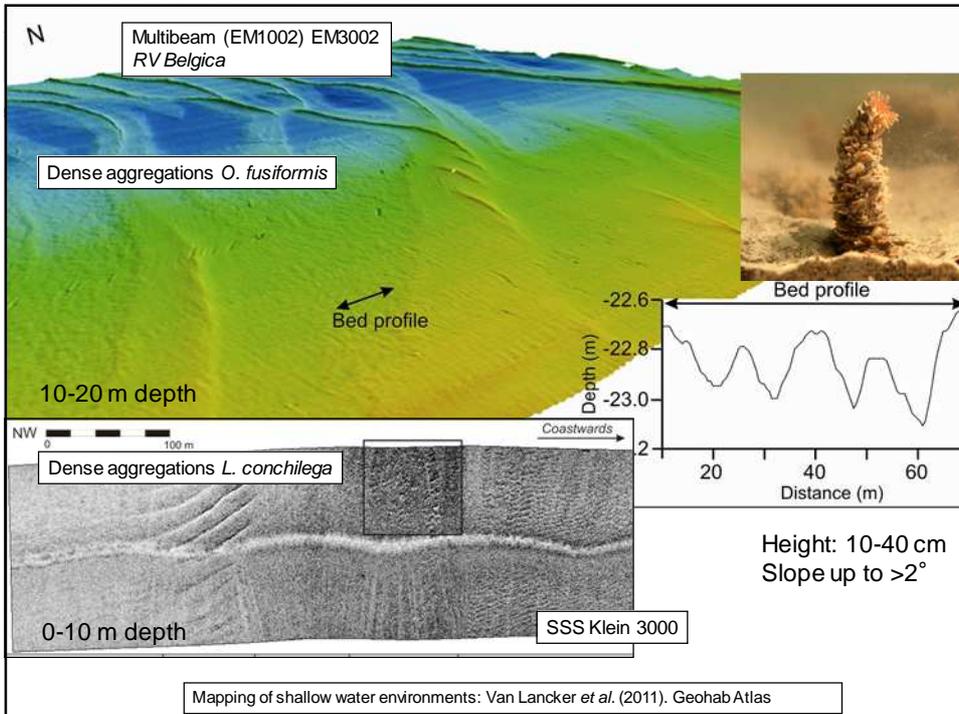


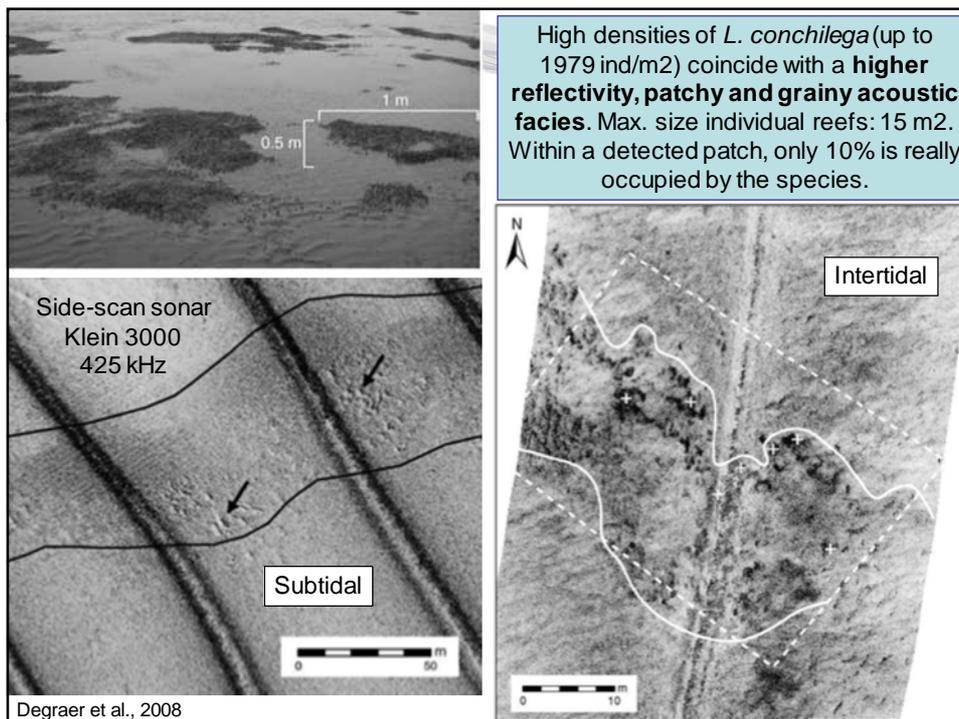
Annex 1 Habitat 1170

Need for fine-scale mapping <5m

Marijn Rabaut

Rabaut, 2010

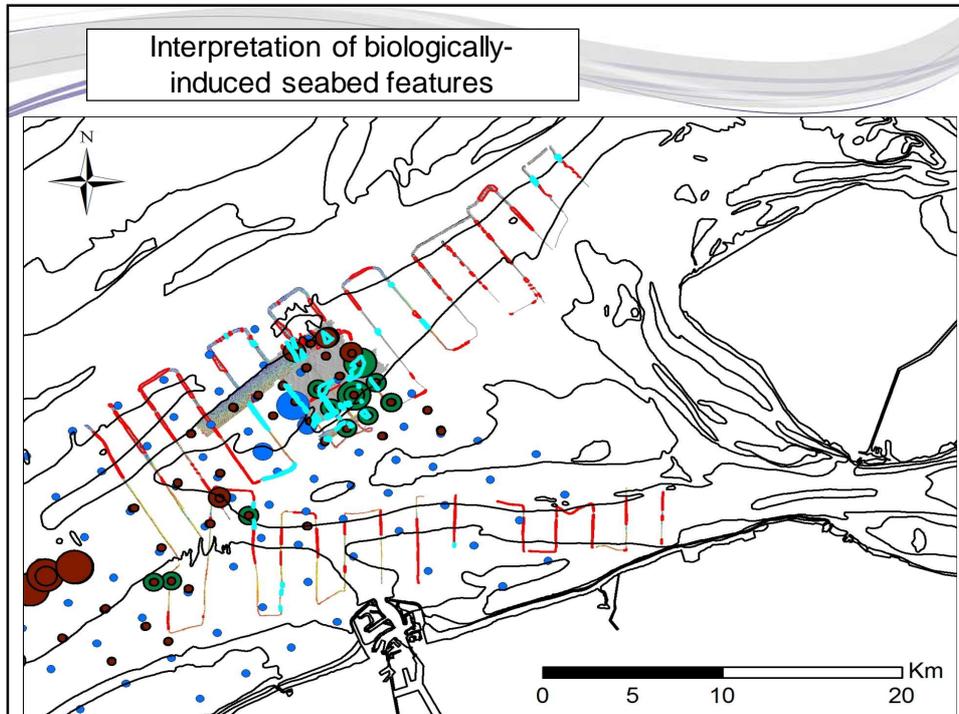
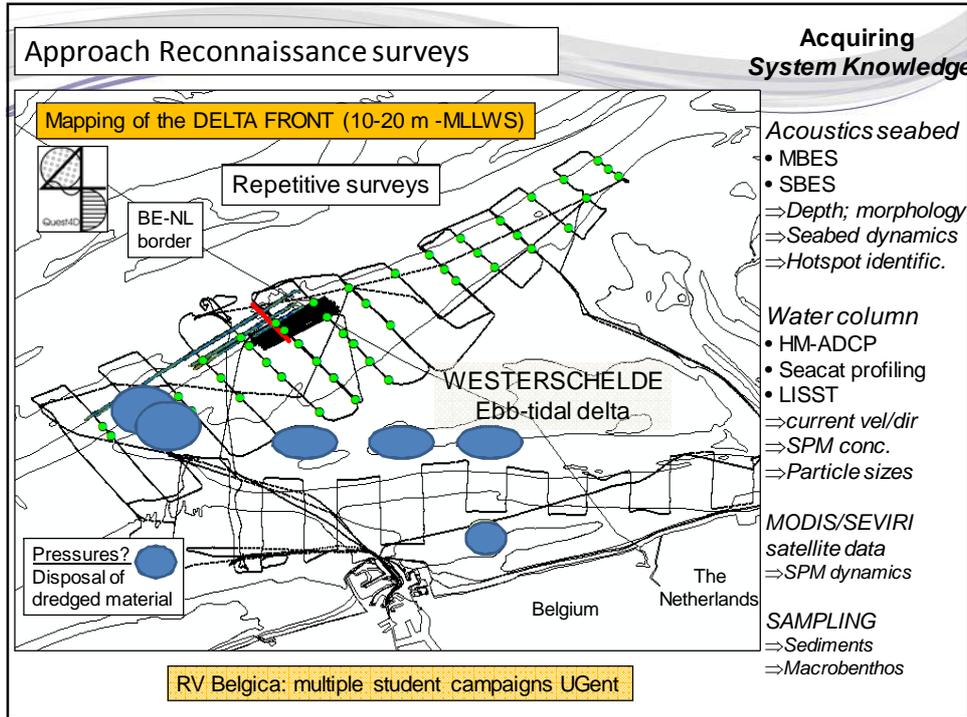


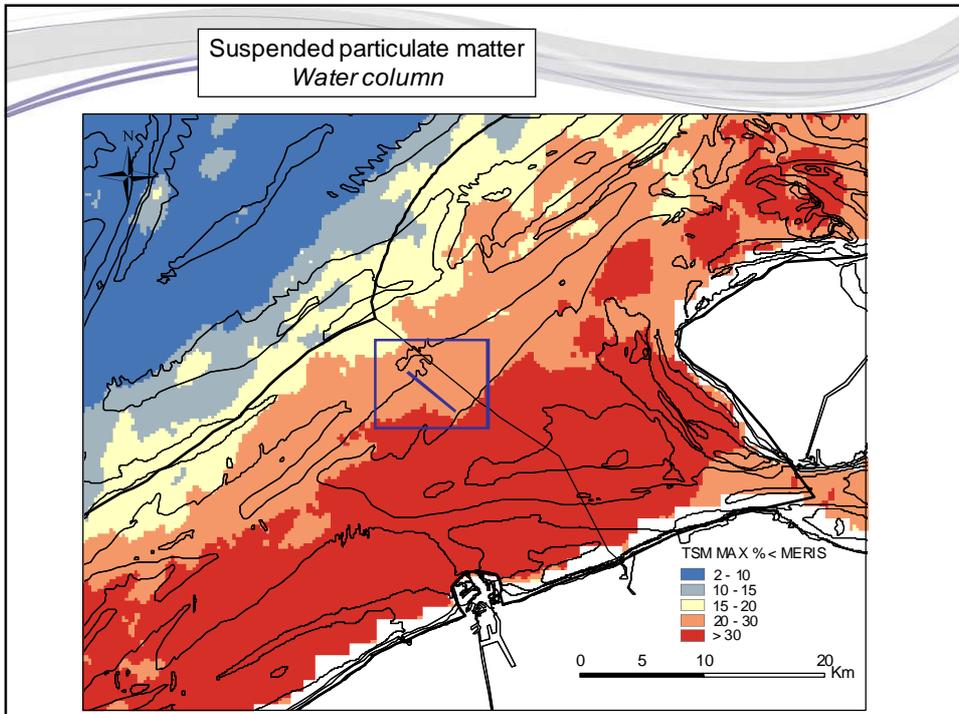
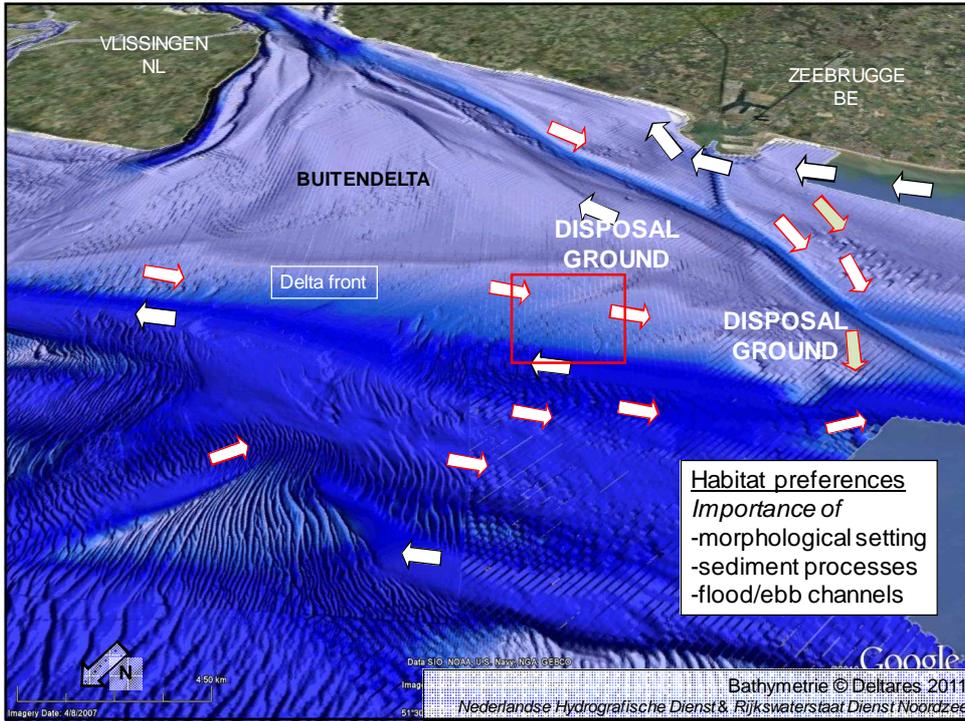


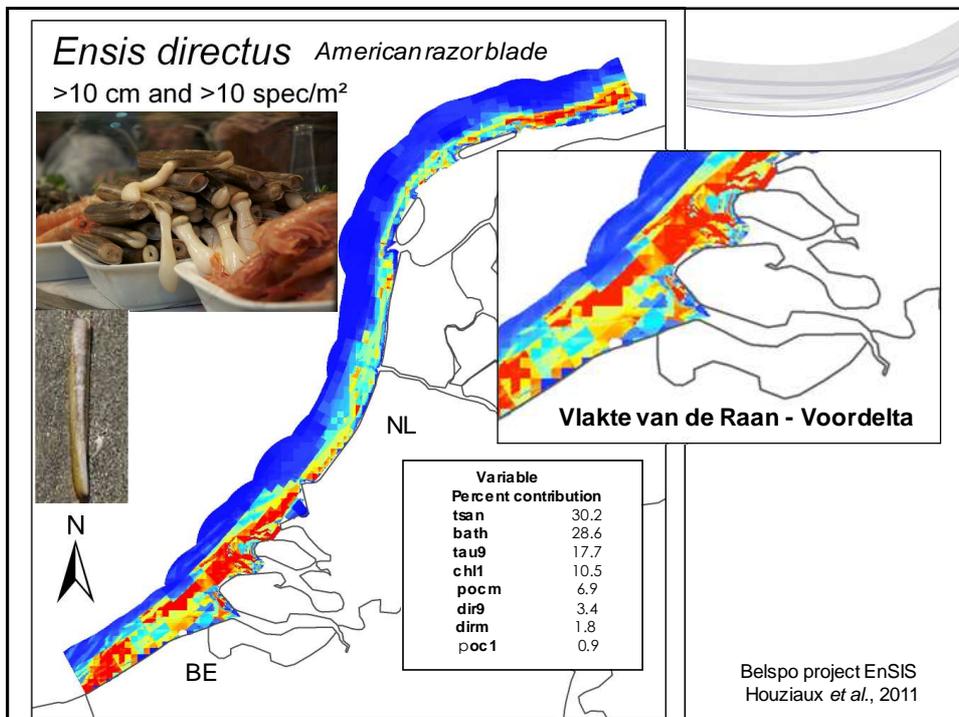
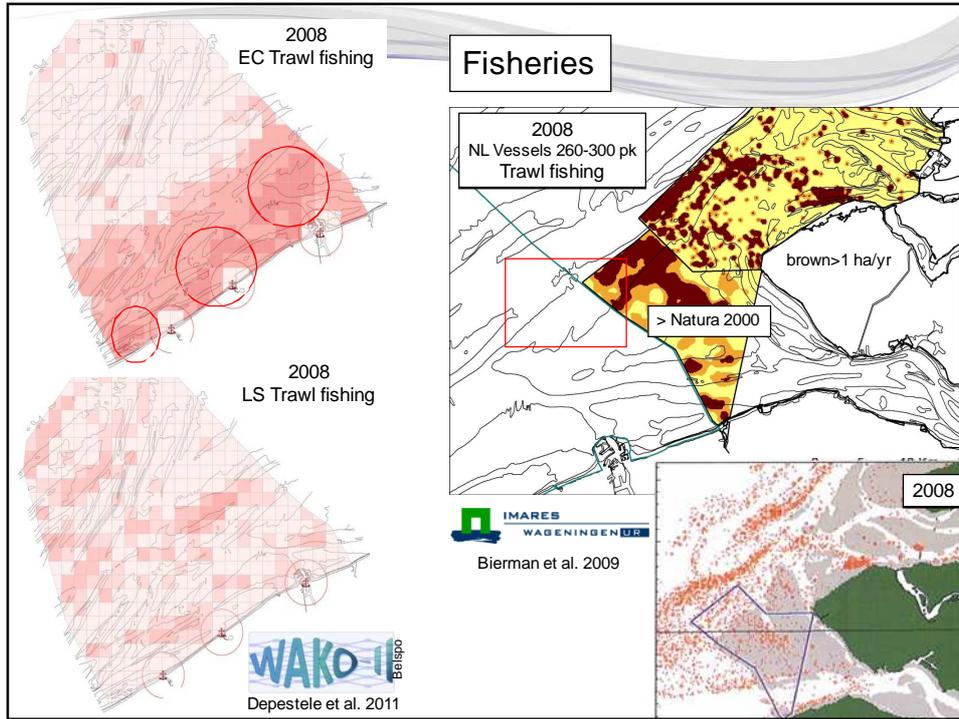
Standardised interpretation of acoustic imagery for shallow sandbank environments
Link of acoustic facies to macrobenthic community preference (Van Lancker et al., 2011)

Geomorphology	Acoustic facies			Interpretation			
	Reflectivity (R) Texture (T)	Pattern	Class	Bedforms	Sediments	Macrobenthic community	
Sandbank Troughs	R T	Low Smooth	Featureless	1		(Fluid) Mud	(A) B
	R T	Medium Smooth-Grainy	Featureless	2		Very-fine to fine sands, high silt-clay %	(A) B
Secondary relief in troughs (e.g. terraces)	R T	Medium Grainy	Straight to sinuous lineations of higher reflectivity, shadow effects	3	Small to medium dunes	Fine to medium sand	C
	R T	Medium Grainy	Straight to sinuous lineations of higher reflectivity, shadow effects	4	Medium to large dunes	Medium sand with shell debris	(C) D
	R T	Medium-High Grainy	Circular to elongated patches with varying reflectivity	5	Small mound features	Fine to medium sand with silt-clay enrichment	B
	R T	High Rough	Alternating high and low reflectivity bands	6	Ribbons Scoured relief	Medium to gravelly coarse sands; gravel	C D
Shoreface / Sandbank Slopes	R T	Low-Medium Smooth-Grainy	Featureless	7		Very fine to fine sands, silt-clay enrichment	A B (C) (D)
	R T	Medium-High Grainy	Circular to elongated patches with varying reflectivity	8	Small mound features	Fine sands with silt-clay enrichment	B
	R T	Medium Grainy	Straight to sinuous lineations of higher reflectivity, shadow effects	9	Medium dunes	Fine to medium sand	C
	R T	Medium Grainy	Straight to sinuous lineations of higher reflectivity, shadow effects	10	Large to very large dunes	Medium sand with shell debris	(A) C
Sandbank Topzones	R T	Low-Medium Grainy	Featureless	11		Fine to medium sand, loosely packed	C
	R T	Medium Grainy	Straight to sinuous lineations of higher reflectivity, shadow effects	12	Small to medium dunes	Medium sand, loosely packed	C (D)
	R T	Medium-High Grainy	Straight to sinuous lineations of higher reflectivity, shadow effects	13	Large to very large dunes	Medium sand with shell debris	C D
	R T	High Grainy to Rough	Featureless	14		Coarse sand with shell debris	D
	R T	High Grainy to Rough	Straight to sinuous lineations of higher reflectivity, shadow effects	15	Symmetrical bedforms (wave-induced)	Coarse sand with shell debris	D

A: *Macoma balthica* community; B: *Abra alba* community; C: *Nephtys cirrosa* community; D: *Ophelia limacina* community; (): less likely



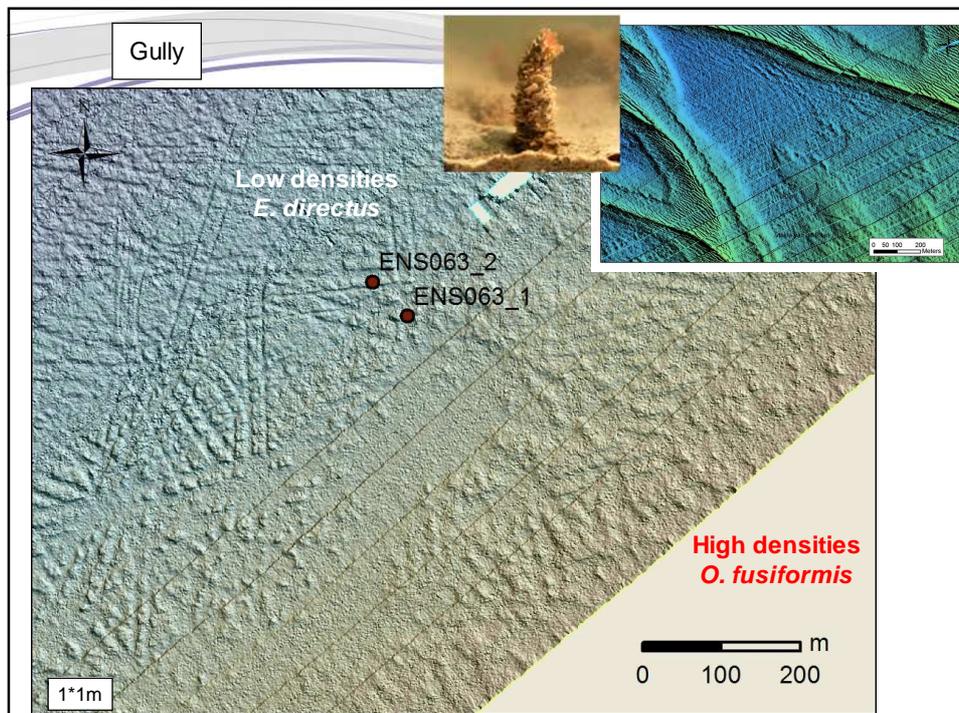


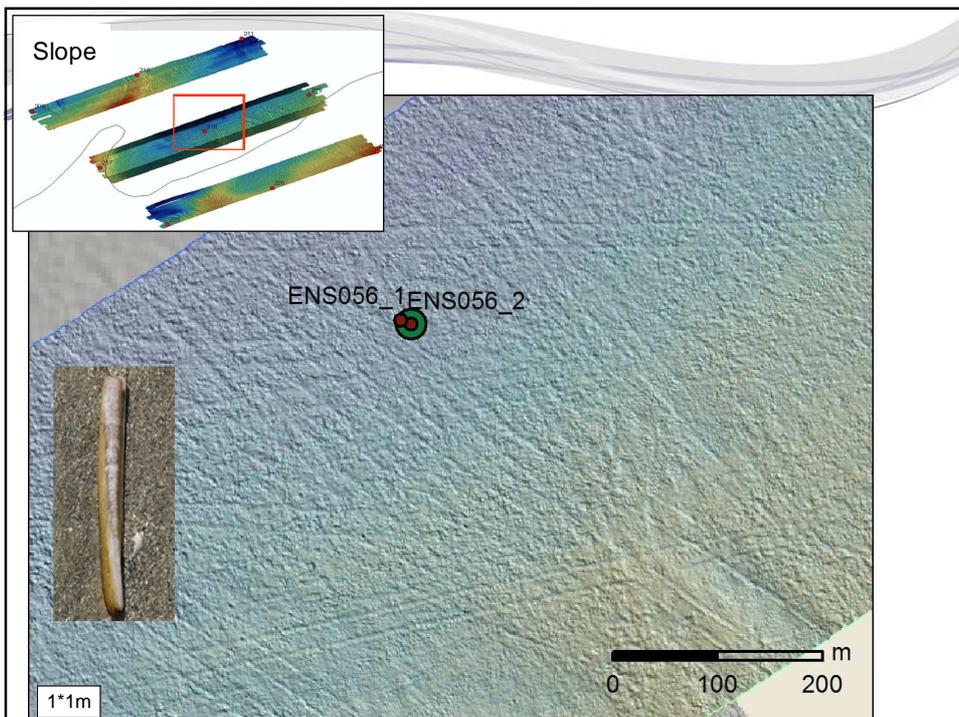
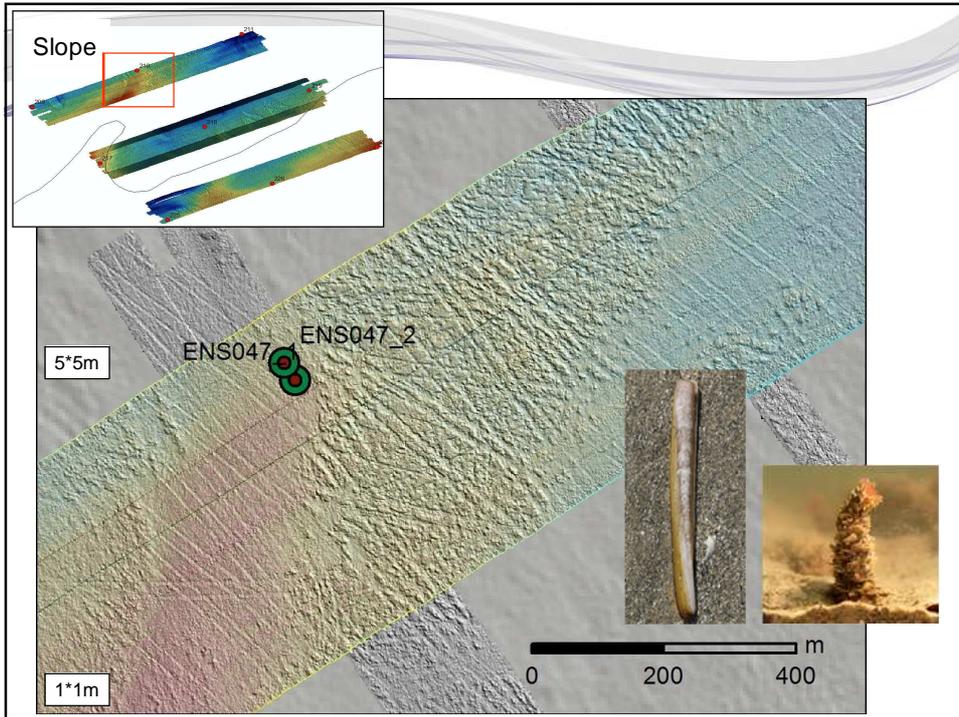


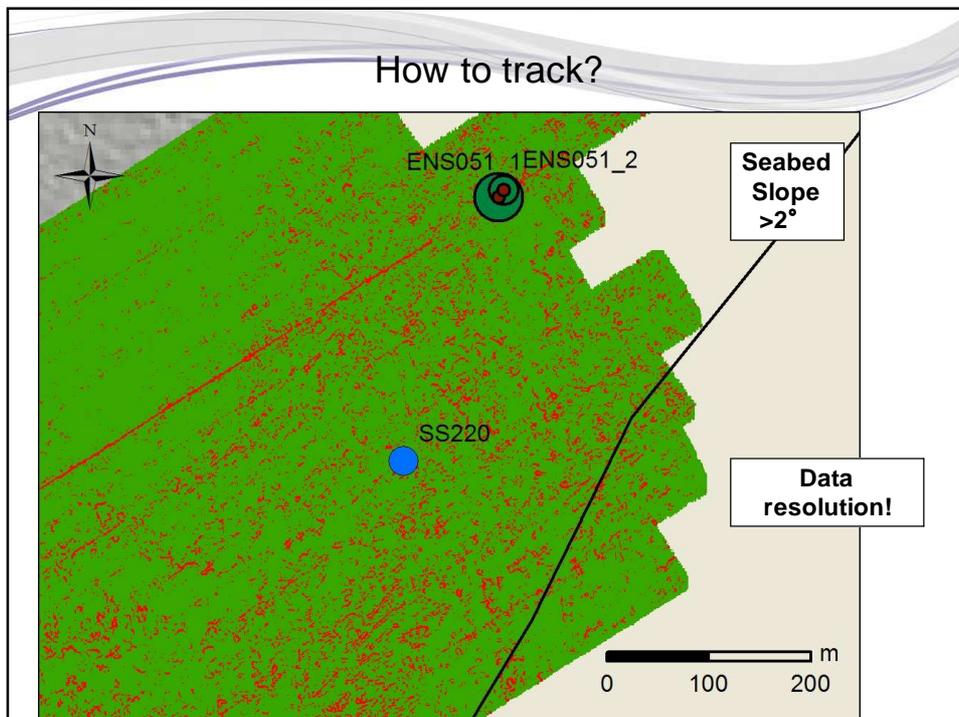
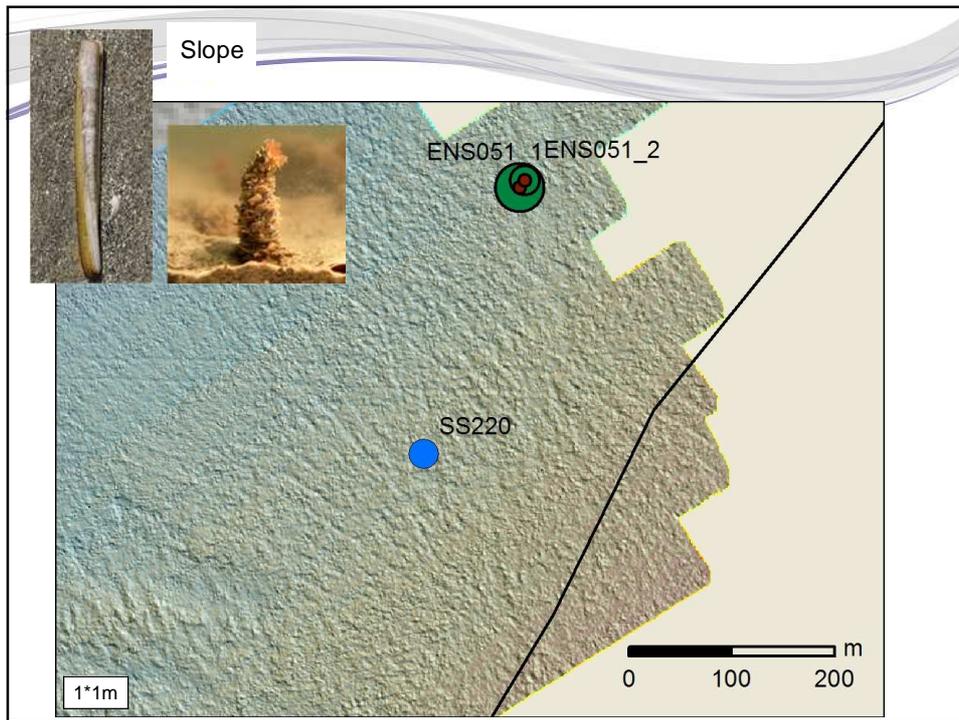
Habitat Preferences

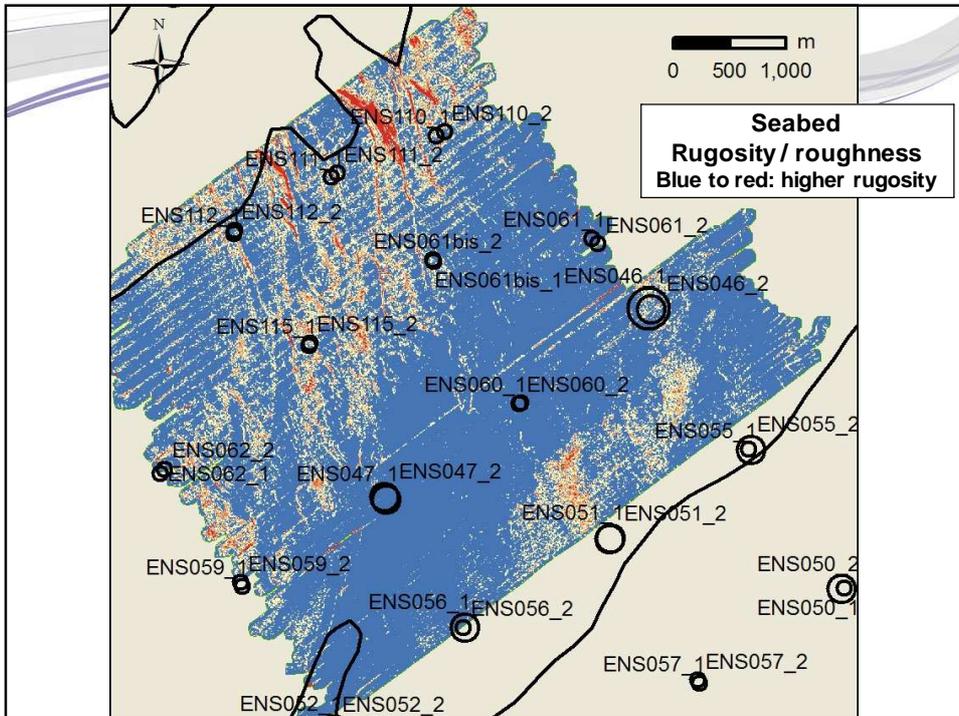
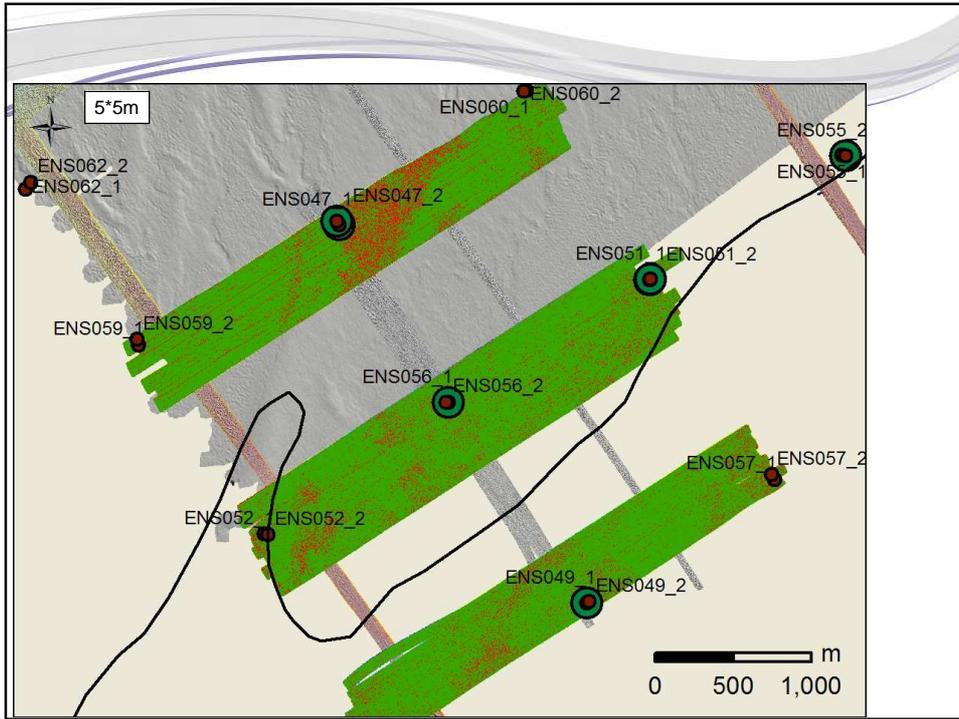
Habitat suitability modelling & Literature

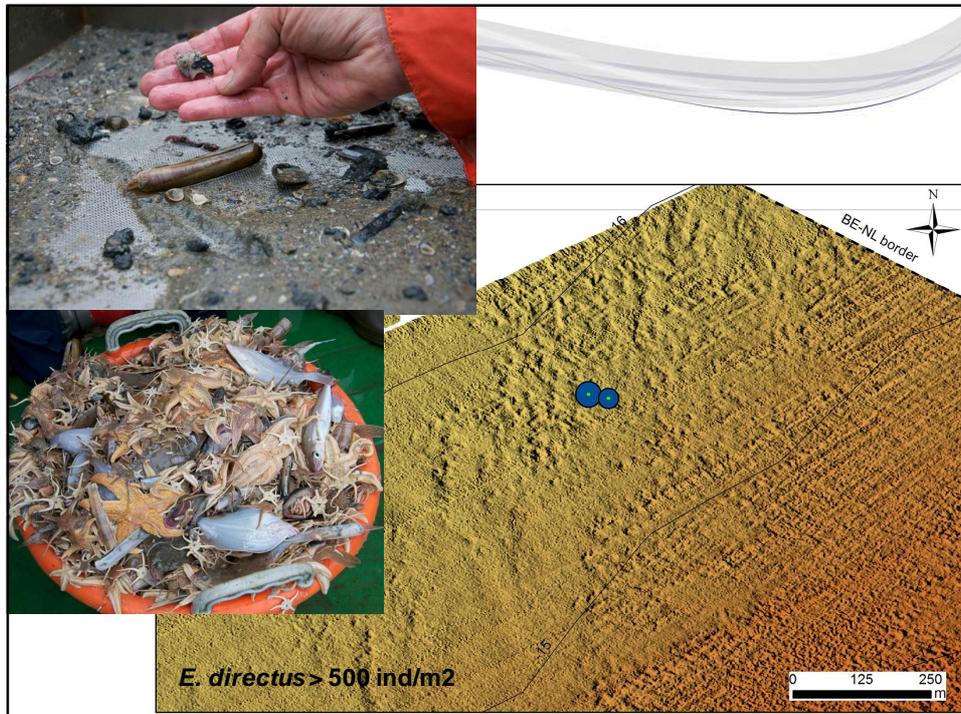
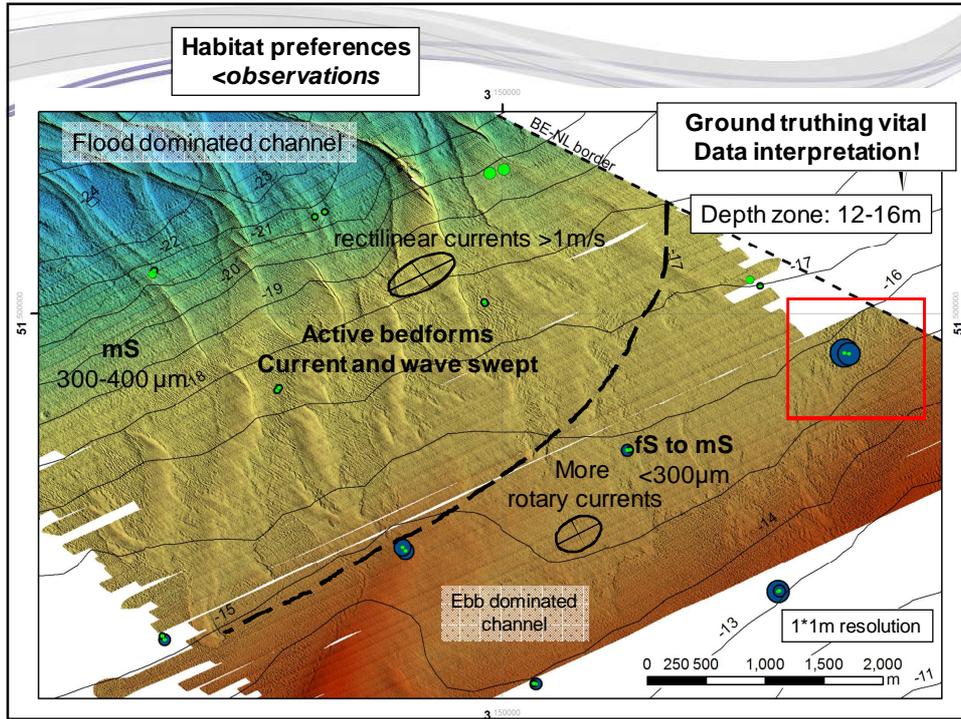
- High max. Chla
- Total suspended matter
 - *can accommodate fluctuations in SPM?*
- Bottom shear stress (max 4 N/m²)
- Depth (12-23m)
- Sand fraction
- Limited tolerance to hypoxia?
- Preference for moving sands and strong currents?

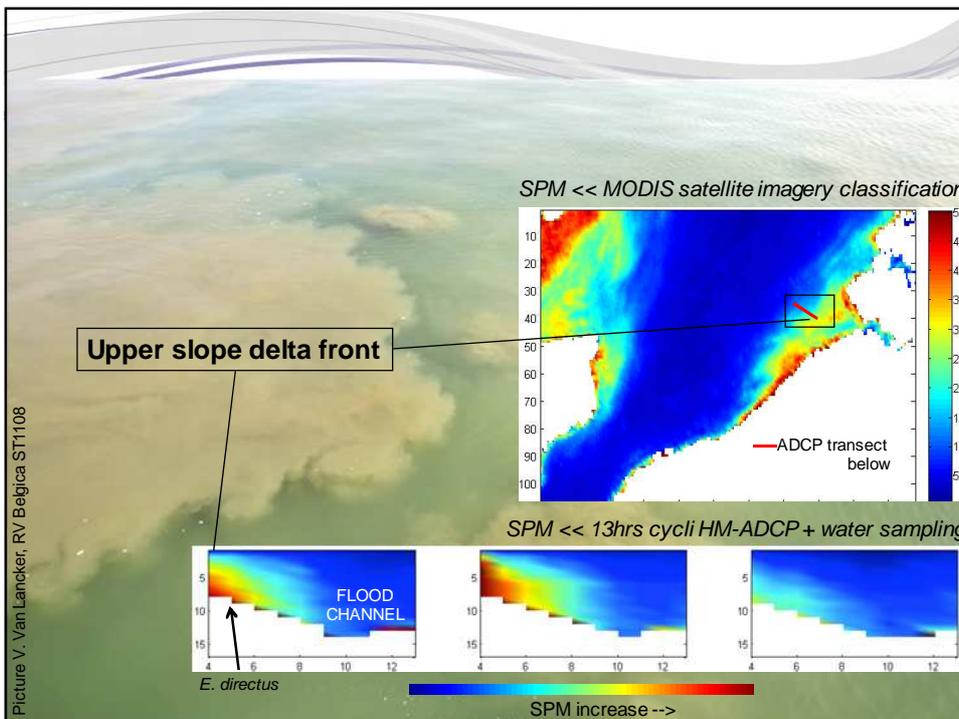
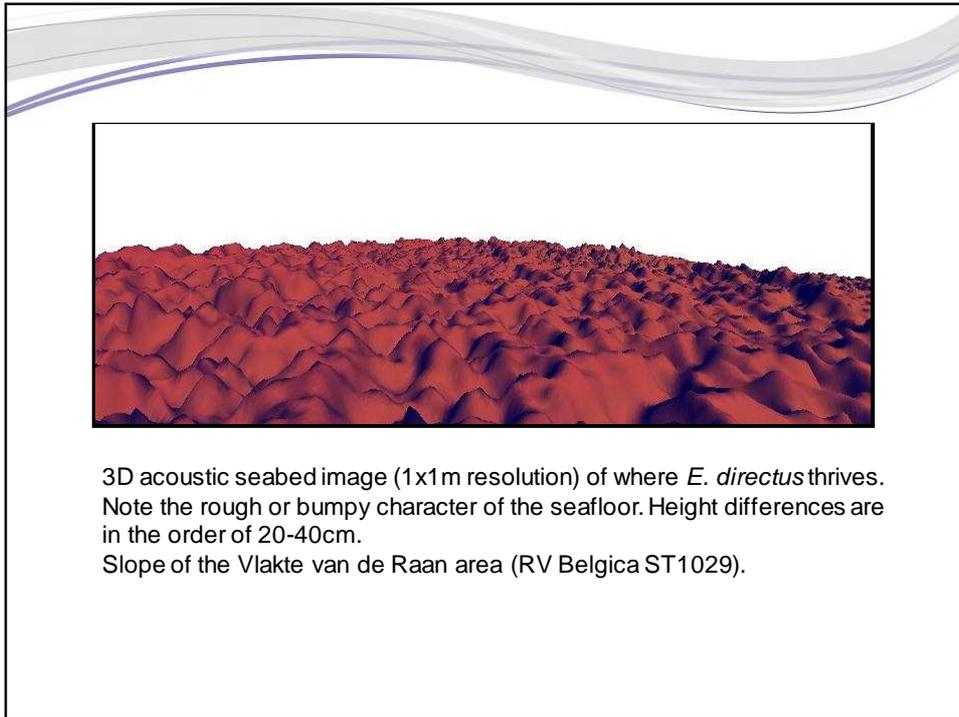




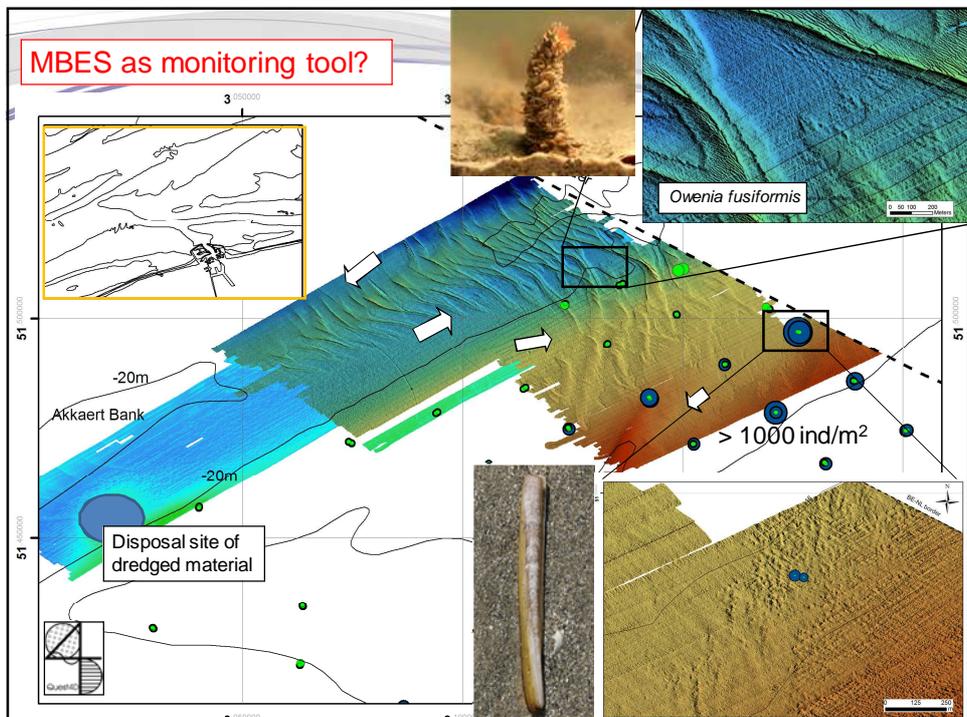


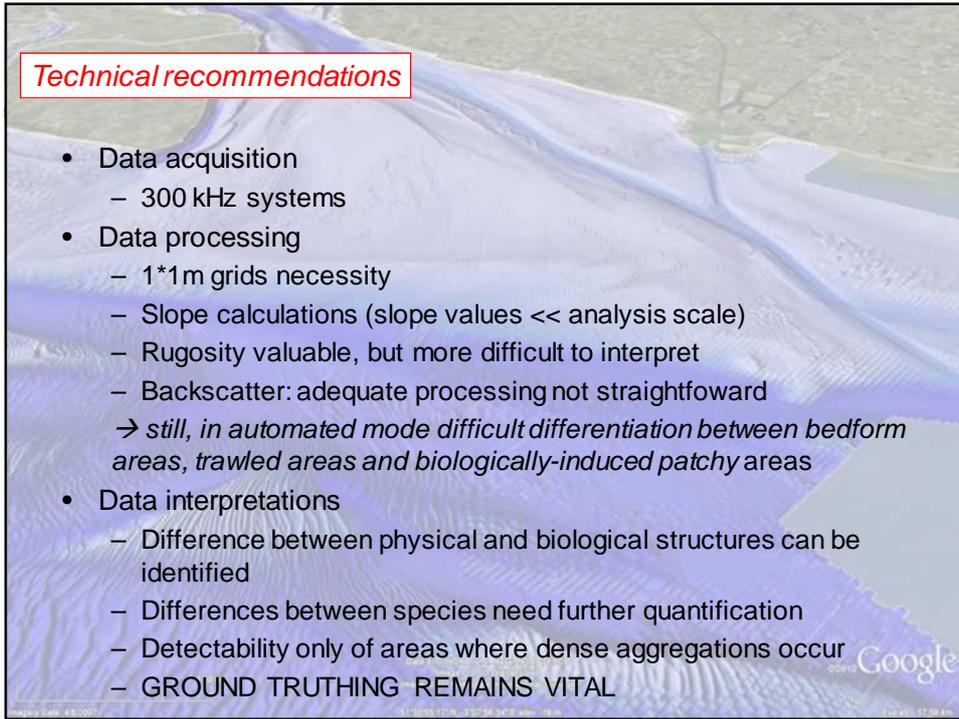






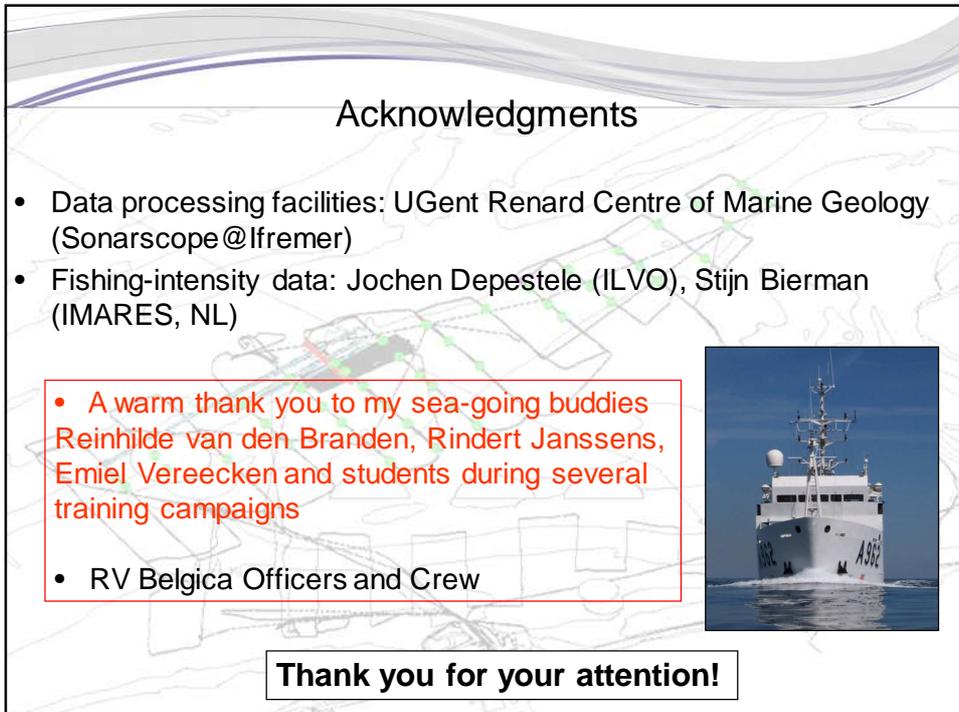
Conclusions





Technical recommendations

- Data acquisition
 - 300 kHz systems
- Data processing
 - 1*1m grids necessity
 - Slope calculations (slope values << analysis scale)
 - Rugosity valuable, but more difficult to interpret
 - Backscatter: adequate processing not straightforward
 - *still, in automated mode difficult differentiation between bedform areas, trawled areas and biologically-induced patchy areas*
- Data interpretations
 - Difference between physical and biological structures can be identified
 - Differences between species need further quantification
 - Detectability only of areas where dense aggregations occur
 - GROUND TRUTHING REMAINS VITAL



Acknowledgments

- Data processing facilities: UGent Renard Centre of Marine Geology (Sonarscope@Ifremer)
- Fishing-intensity data: Jochen Depestele (ILVO), Stijn Bierman (IMARES, NL)

- A warm thank you to my sea-going buddies Reinhilde van den Branden, Rindert Janssens, Emiel Vereecken and students during several training campaigns

- RV Belgica Officers and Crew



Thank you for your attention!

Supervised segmentation of sonar image : application for stock assessment of oysters and crepidula in Quiberon Bay (France)

J-Y. Stanisière¹, J-M. Augustin³, J-M. Siquin³, E. Leclerc¹, K. Quinsat²,
A. Langlade¹, J-F. Bouget¹, J. Mazurié¹

1) Ifremer, BP86, 56470 La Trinité-sur-mer (France)

2) Université de Bretagne Sud Vannes (France)

3) Ifremer Brest (France)



Focus on the Quiberon Bay

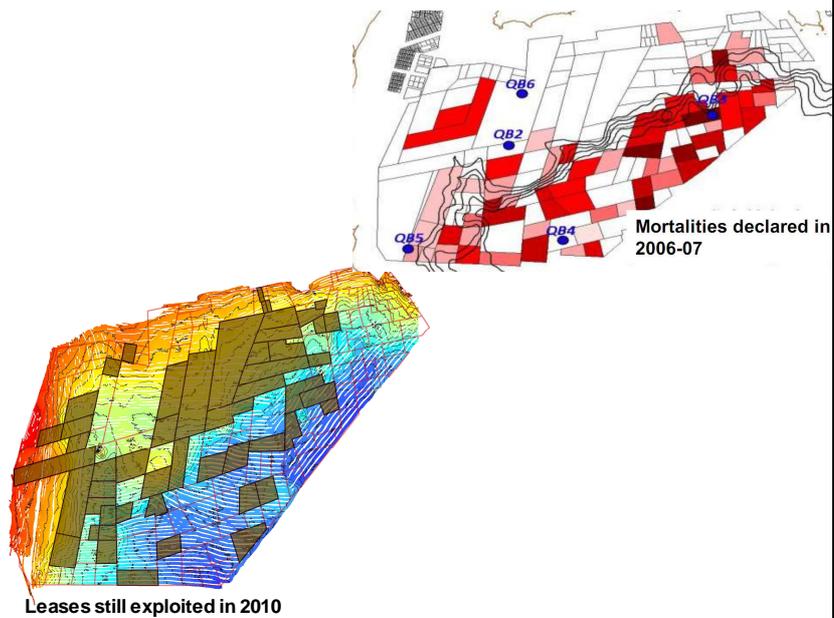
- Quiberon Bay (south Brittany, France) is a subtidal oyster rearing site (2800 Ha of leases, 80 farms, 15 000 tons).
- Two species are cultivated *Ostrea edulis* (flat oysters) and *Crassostrea gigas* (cupped oysters).
- Rearing during 1 to 3 years on the bottom without protection (barges with dredges are employed for harvesting)
- Since 6 years abnormal mortalities (range 50 to 90%) affected oysters (young and adults), mainly in deeper and muddy leases
- Severe economic / social consequences : unprofitability, disengagement from leases, workers dismissals



Focus on the Quiberon Bay



Focus on the Quiberon Bay



Context

- A research program was undertaken to explain the mortalities
- Funded by Regional authorities of Brittany
- This study implicates both industry, socio-economic experts and biologists, with an interdisciplinarity approach.
- The program aims at applied results, through risk management.

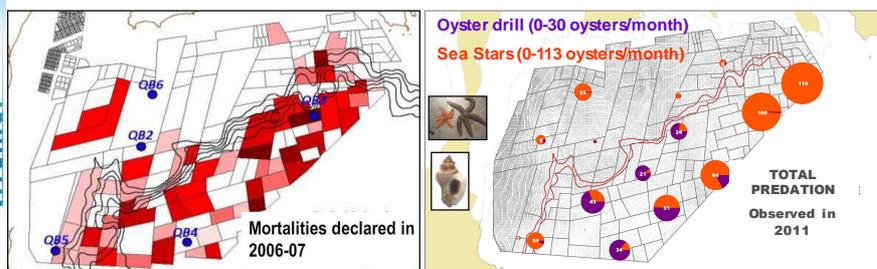


Context

The study lead by Ifremer have 3 axes

Axe1 : Determine the causes of mortalities

In 2011 a monitoring in 15 points concluded to a dominant effect of predation on mortalities (sea stars and oyster drills) of adult oysters. Herpes OsHV1 μ var for spats



Context

Axe2 : Characterization of the environnement

- Bathymetry, nature of bottom, shellfish stock (sonar and video acquisition, sediment sampling).
- Hydrodynamic component (3D models, ADCP acquisition)
- Hydrology of the water column (T/P/S/Fluo/Turb profiles, satellite data, monitoring phytoplankton species)

Axe3 : Influence of environnement on oyster physiology

- Spatialize risk components



Context

The study lead by Ifremer consisted in 3 axes

Axe2 : Characterization of the environnement

- Bathymetry, nature of bottom, **stock of shellfish** (sonar and video acquisition, sediment sampling).
 - Hydrodynamic component (3D models, ADCP acquisition)
 - Hydrologic of the water column (T,P,S,Fluo,Turb Profils/Satellite data)
- Axe3 : Influence of environnement on oyster physiology
- Spatialize risk component



Supervised Segmentation of Texture



Acoustic remote sensing, such as high-resolution multibeam and sidescan sonar, provides new means for in-situ observation of seabed

The segmentation and the classification of sonar image with respect to seafloor type (sand, mud rocks...) is the key goal behind the analysis of these acoustic images.

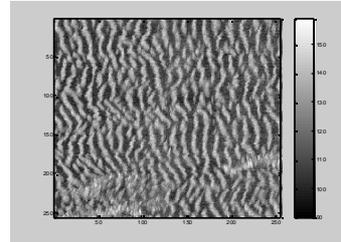
In this study we applied a supervised segmentation of texture



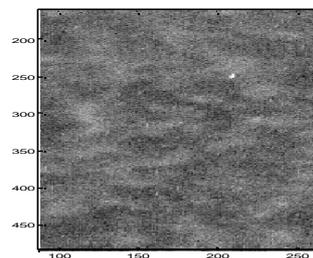
Texture in image sonar

A texture appears if :

The bathymetry is spatially « organized »
Ex : sand ripples

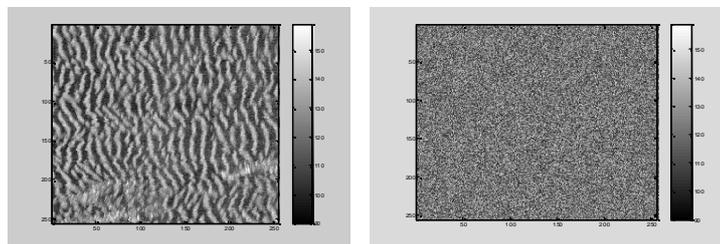


The seabed nature is spatially « organized »
Ex : shellfish beds



Mathematic tools : first order statistics ?

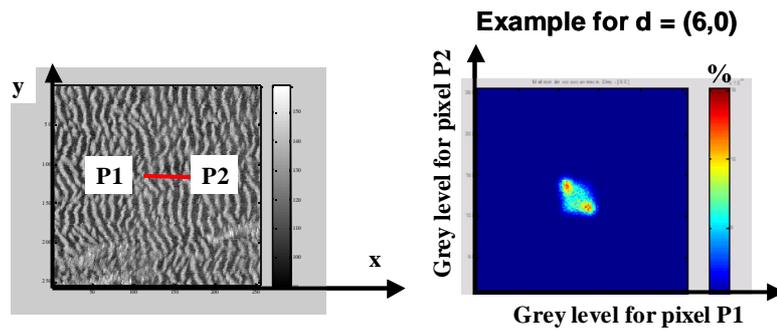
- In the example the right image is a « shaken » version of the left one.
- So their first order statistics (distribution, mean value, std) are the same ...



- Actually their textures are clearly different !!
- So the first order statistics are not sufficient**

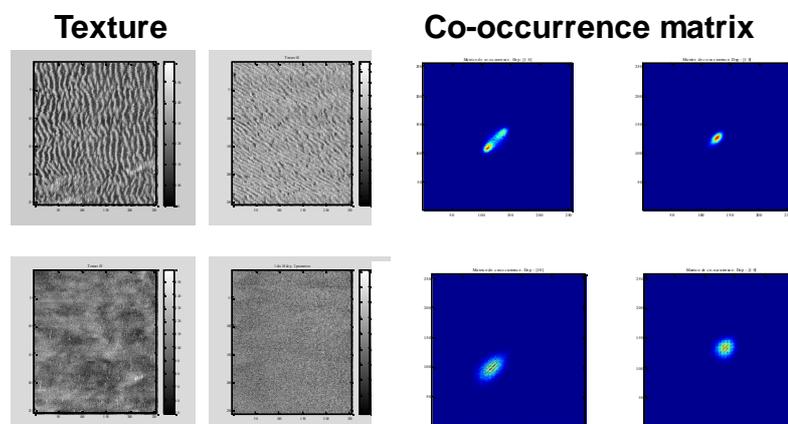
■ The second order statistics (cooccurrence matrices) describe the spatial organization of the pixels (the texture)

- A co-occurrence matrix represents frequency of each couple of pixels (P1,P2) spaced with a distance $d=(dx,dy)$



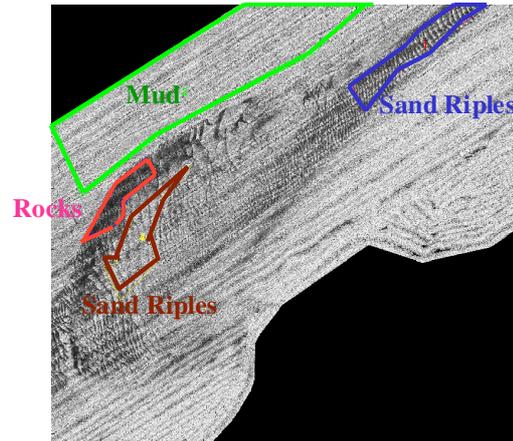
A cooccurrence matrix is a signature of a textured image

■ Textural signatures of 4 textured images $d=(1,0)$



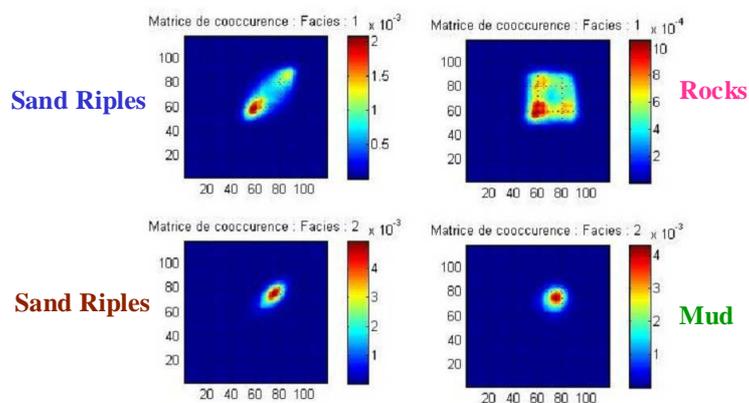
Segmentation algorithm : reference zones

- The scientist isolates the reference zones corresponding to the different seafloor types



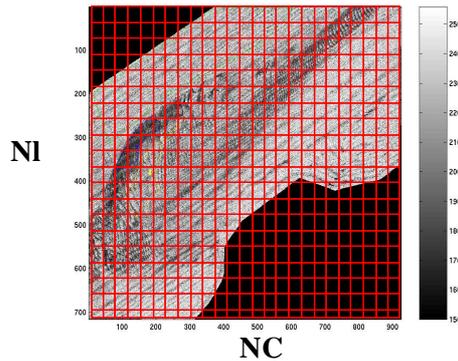
Segmentation algorithm : learning phase

Co-occurrence matrix are computed for each reference zone



Segmentation algorithm : split image

- Split the image into $N_l \times N_c$ smaller images (tiles)
- The scientist chooses the size of tiles ($[32 \times 32]$, $[16 \times 16]$ or even $[8 \times 8]$) and the distance ($d=[dx, dy]$)



- For each tile, a cooccurrence matrix is computed

Segmentation algorithm : similarity measure with references

- For each tile
 - Measurement of the distance to the « N_f » reference matrices
 - Identification of the reference matrix for which the distance is minimum

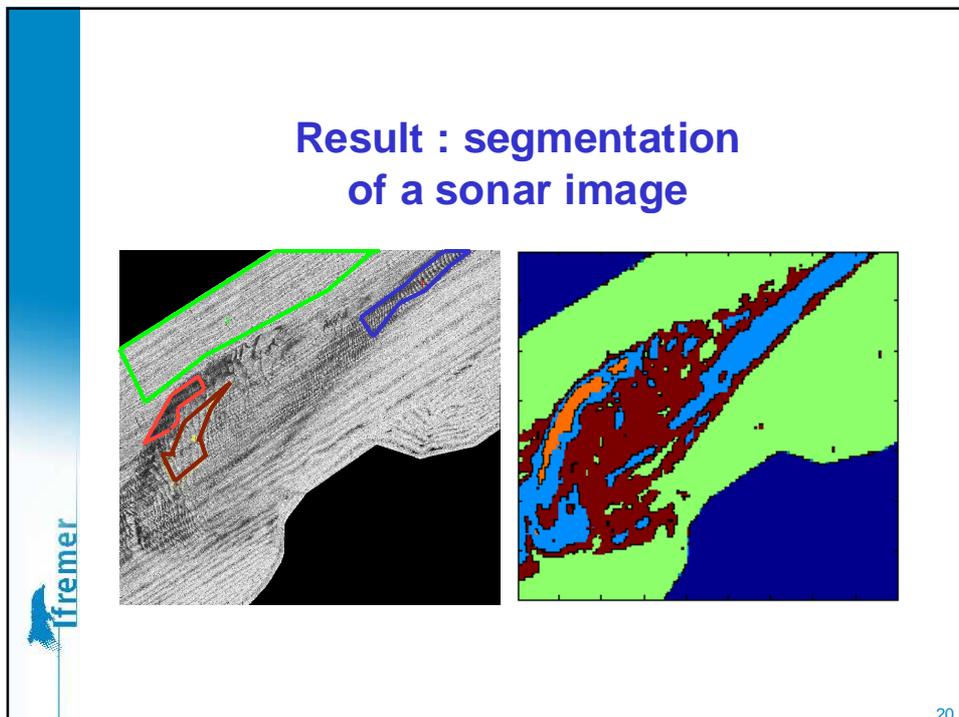
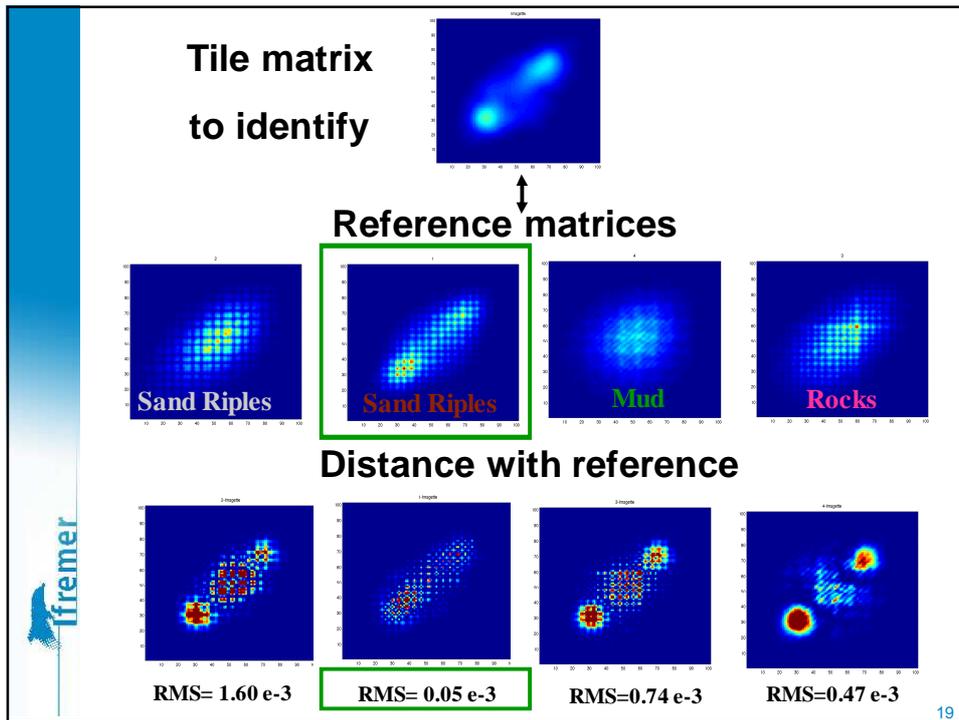
- Distance formula used

- Kullback Distance :
$$K(p, q) = \sum_{i,j} p(i, j) \times \log \left(\frac{p(i, j)}{q(i, j)} \right)$$

$p(i, j)$: values of the cooccurrence matrix of the tile

$q(i, j)$: values of the cooccurrence matrix of the reference image

i : grey level of the first pixel. j : grey level of the second pixel

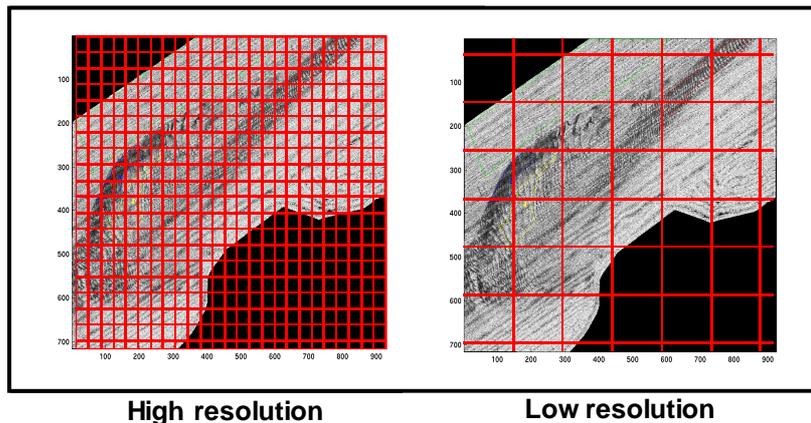


Difficulties

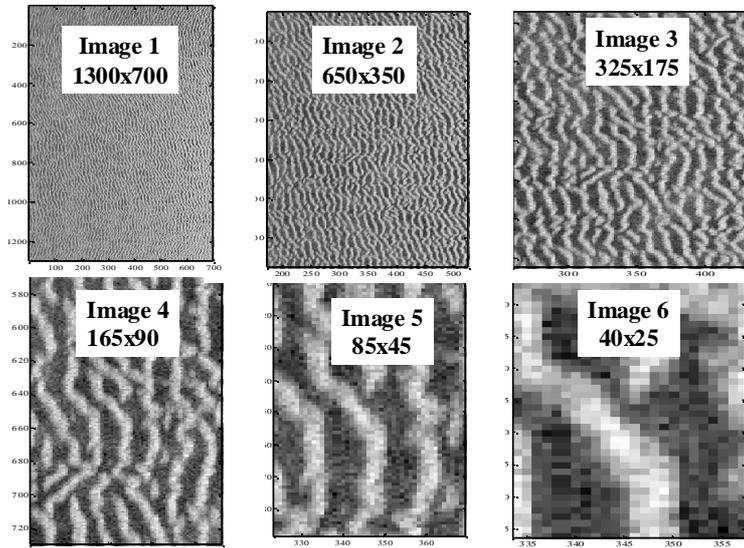
The size of tiles is a compromise between resolution and accuracy of the segmentation



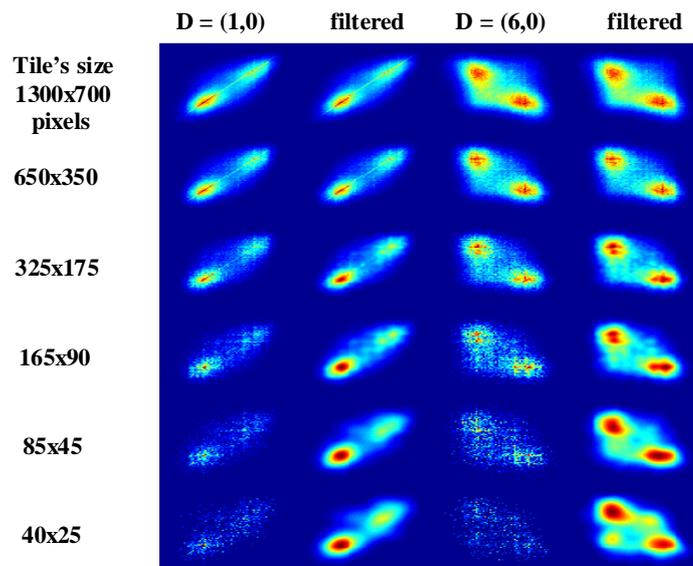
Largest size provide a poor resolution of the segmentation



Persistence of the signature according to tile's size ?



Smallest size of tiles provide low accuracy

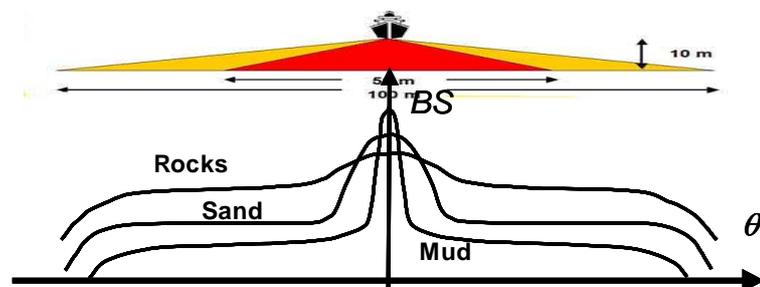


Difficulties

The texture is angular dependent

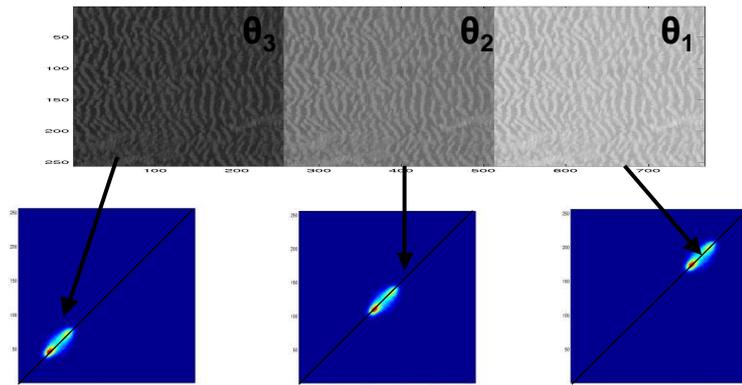
Angular dependency of the texture

- The mean value of a sonar image depends on the incidence angle and the nature of the seabed
- The cooccurrence matrix is sensitive to the mean value



Angular dependency of the texture

- The mean value depends on the incidence angle.
Consequence : the cooccurrence matrix is moving along the diagonal

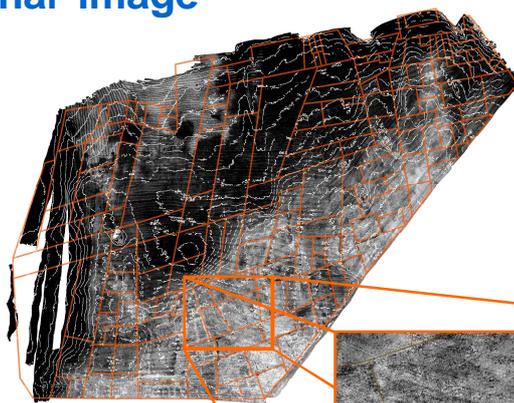


Application in stock mapping in Quiberon Bay

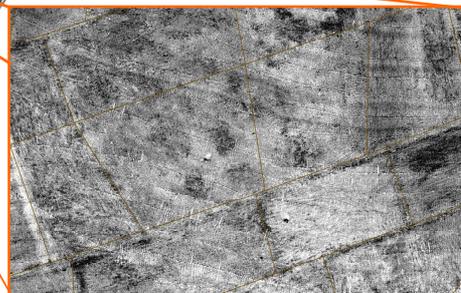
The Data

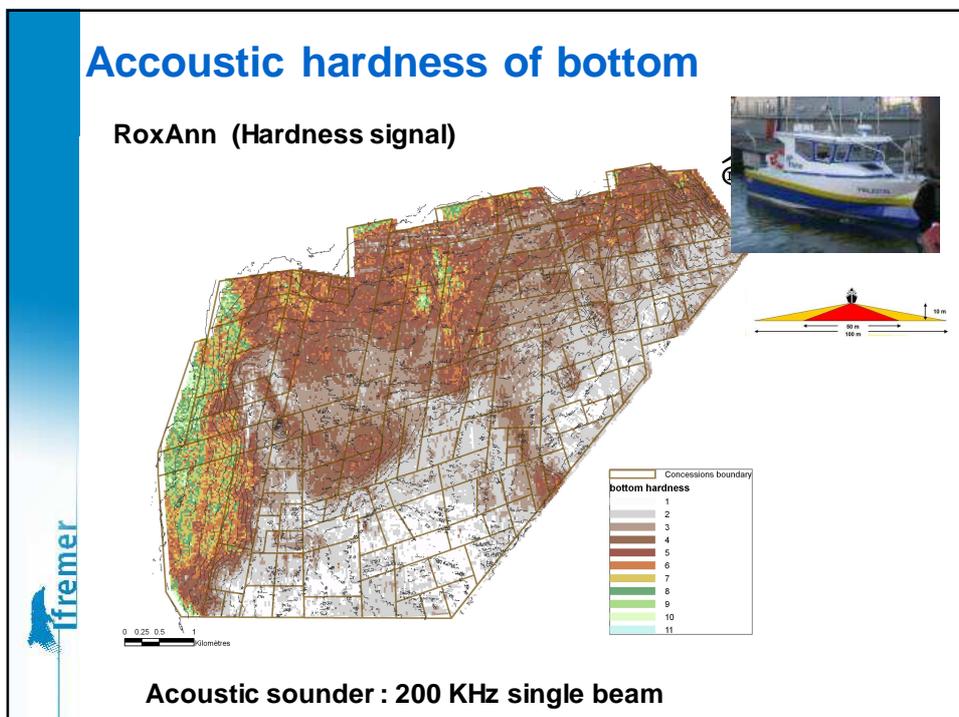
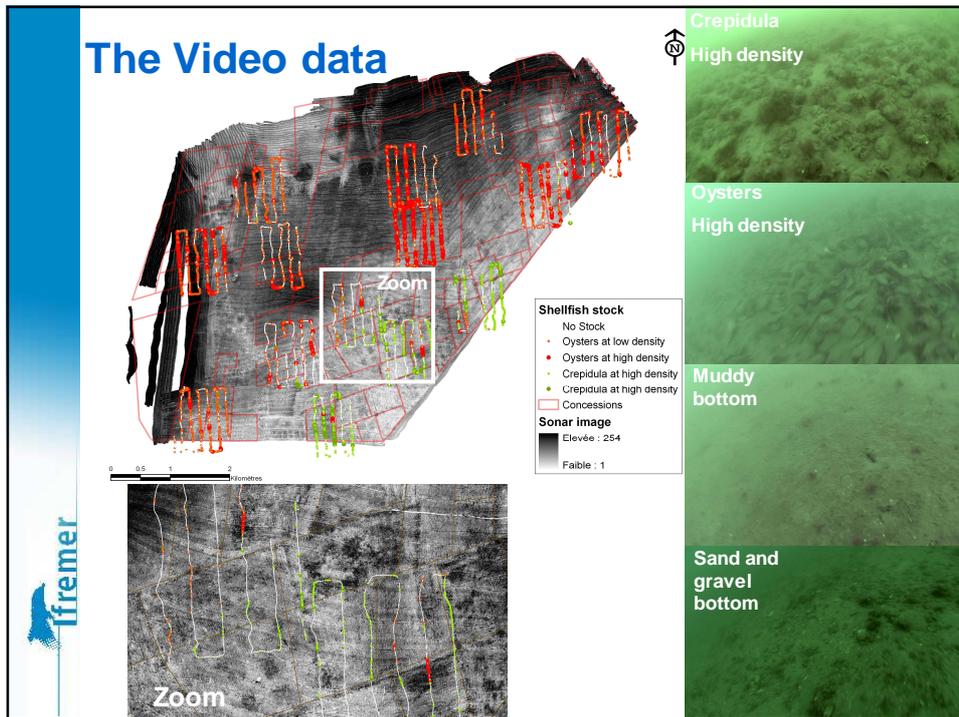


Sonar image

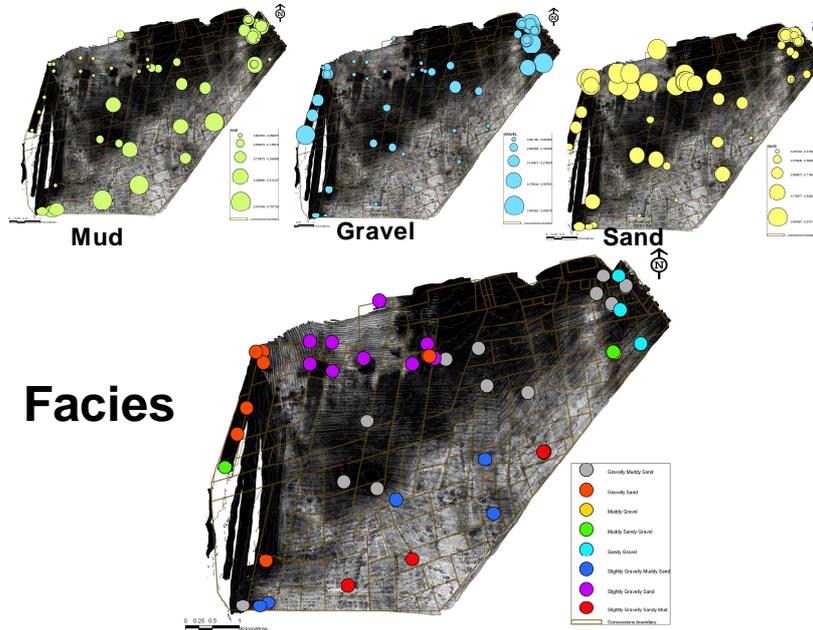


Interferometric sonar

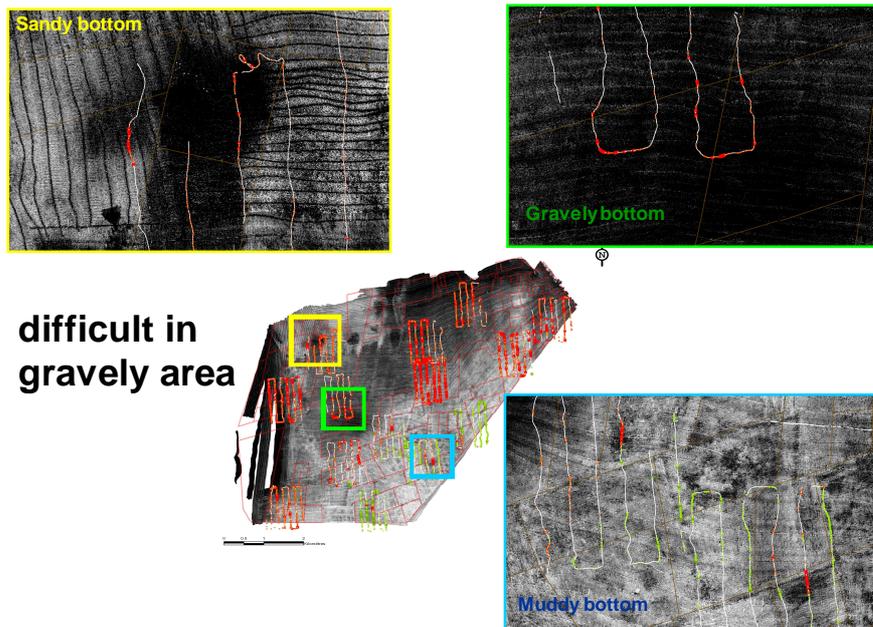




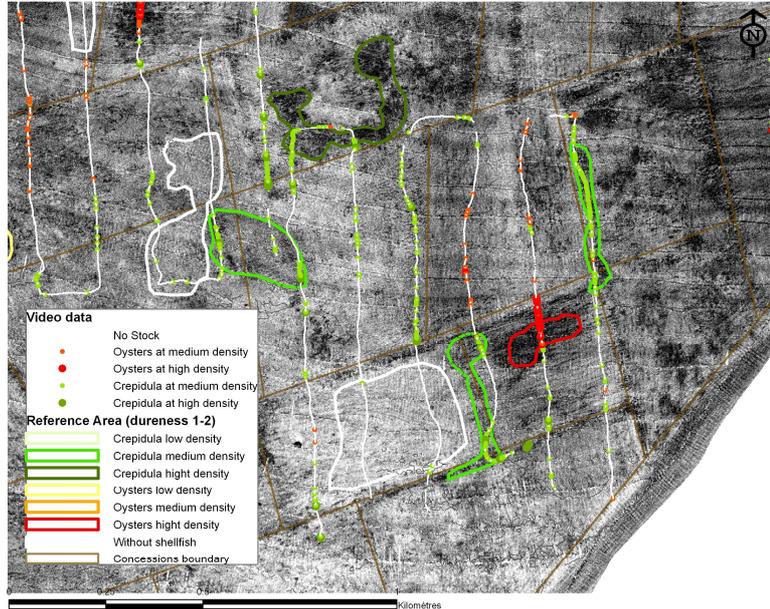
Sediment sampling (grab)



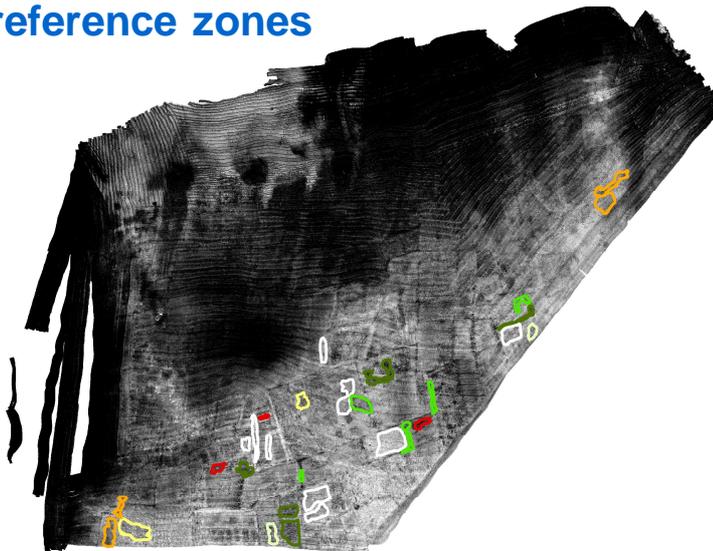
Influence of sediment on detection of shellfish

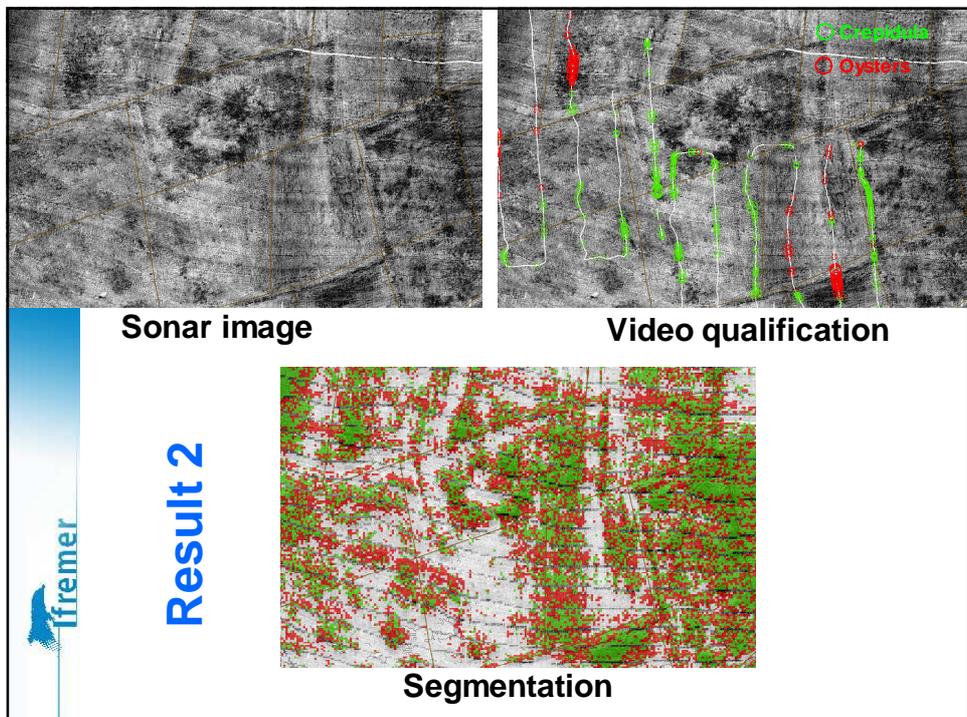
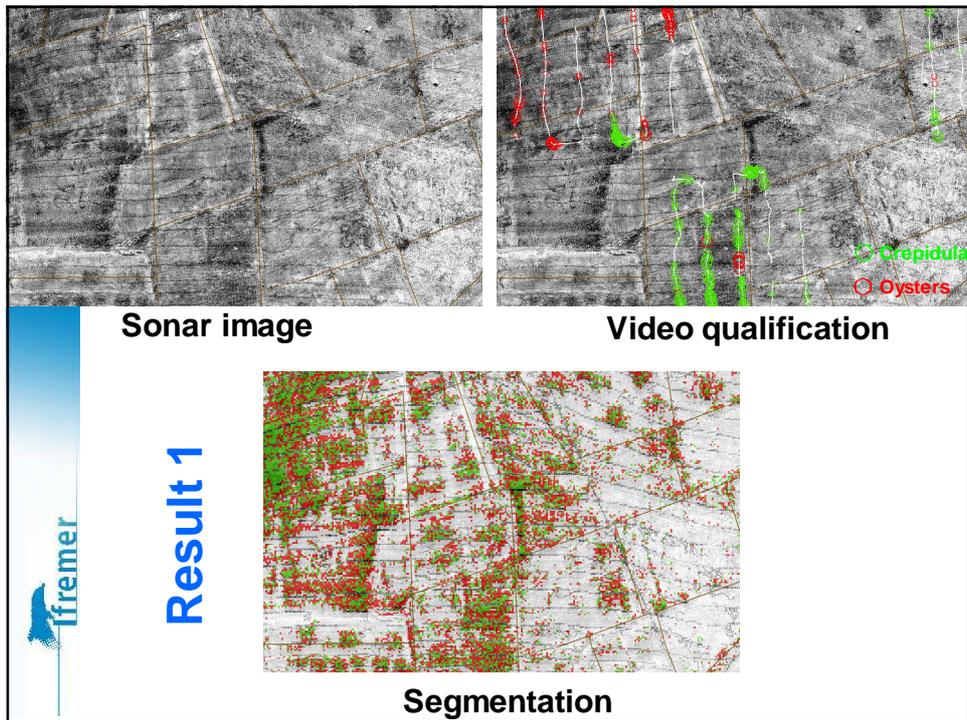


Testing in muddy area : 32 reference zones

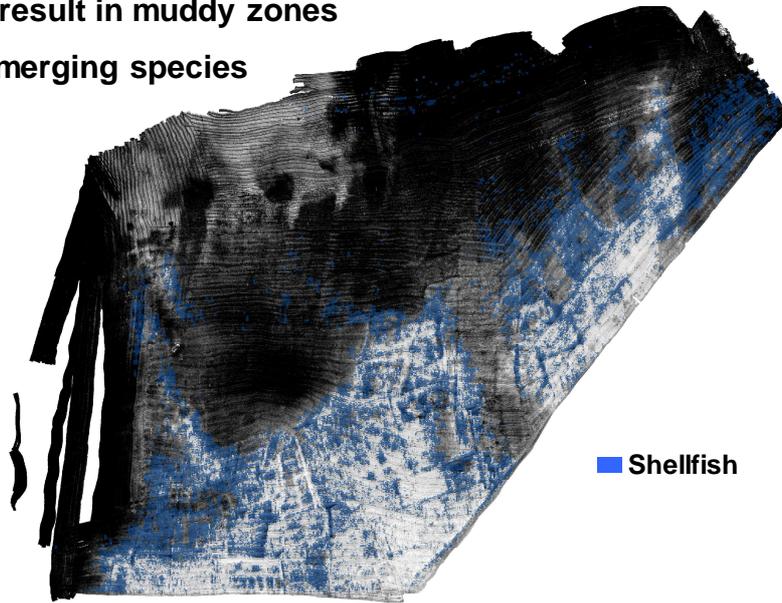


Testing in muddy area 32 reference zones





**Final result in muddy zones
after merging species**



Conclusions

- The segmentation of shellfish on bottom is efficient except in sector with high gravel fraction
- The distinction between crepidula and oysters is quite difficult
- The density of shellfish beds cannot be well estimated
- The signal texture doesn't discriminate dead and living shellfish

An improvement of the method is been tested

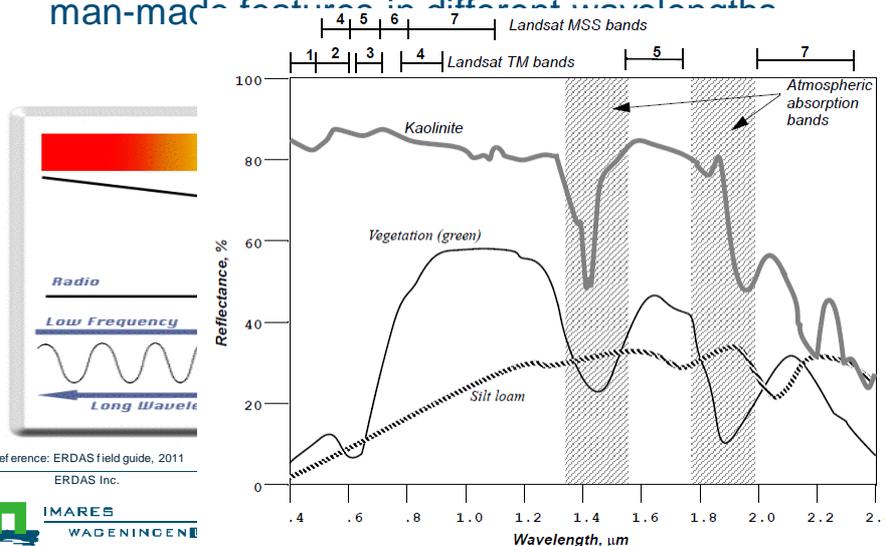
Classification of emerging tidal flats using remote sensing data (possible application for stock assessments)

Narangerel Davaasuren, Cor Smit, Johan Stapel,



Remote Sensing- short introduction

- Main basis- recording reflectance of natural and man-made features in different wavelengths



Bands Landsat TM		Band	Wavelength (microns)	Comments
30 meters		1, Blue	0.45 to 0.52 μm	This band is useful for mapping coastal water areas, differentiating between soil and vegetation, forest type mapping, and detecting cultural features.
		2, Green	0.52 to 0.60 μm	This band corresponds to the green reflectance of healthy vegetation. Also useful for cultural feature identification.
		3, Red	0.63 to 0.69 μm	This band is useful for discriminating between many plant species. It is also useful for determining soil boundary and geological boundary delineations as well as cultural features.
		4, NIR	0.76 to 0.90 μm	This band is especially responsive to the amount of vegetation biomass present in a scene. It is useful for crop identification and emphasizes soil/crop and land/water contrasts.
		5, MIR	1.55 to 1.75 μm	This band is sensitive to the amount of water in plants, which is useful in crop drought studies and in plant health analyses. This is also one of the few bands that can be used to discriminate between clouds, snow, and ice.
		6, TIR	10.40 to 12.50 μm	This band is useful for vegetation and crop stress detection, heat intensity, insecticide applications, and for locating thermal pollution. It can also be used to locate geothermal activity.
		7, MIR	2.08 to 2.35 μm	This band is important for the discrimination of geologic rock type and soil boundaries, as well as soil and vegetation moisture content.

Reference: ERDAS field guide, 2011
ERDAS Inc.



Remote Sensing- short introduction

- Increasing applications- marine
 - Chlorophyll, algae detection, changes in cover (ice, land, coastal line)
 - Input to various models- waves simulation, change simulation, etc- based on long-term data
 - Classification of features- emerging, sub-emerging
 - Combination with other data- for visualization, additional source of information



Remote Sensing- project - What do you need

1. Clear objective of the project-
 - Features to detect (presence of algae, etc)
 - If mapping (data in use- field data, measurements), ready product or sketch map, maps for presentation, etc
 - If changes- long-term or short
2. Data to be used
3. Software to be used
4. Administration- hours, labour costs, total costs, time management, etc
6. Other issues- where to publish, present, etc.

Remote Sensing- project- What is possible

1. Good news- possibilities are endless
2. Bad news- possibilities like deep ocean
3. Solution- keep flow in selected themes & start with small projects in new themes

Ocean color

- Ocean color-chlorophyll
- Algae- function of surface light intensity and chlorophyll (biomass)
- MERIS ENVISAT, MODIS AQUA
250 m; 500 m resolution
NOAA- 1 km



The screenshot shows the OceanColor website interface. At the top, there is a navigation menu with links for Missions, Data, Documents, Analyses, People, Forum, Services, and Links. Below this is a large banner image of a global map showing ocean color variations. The main content area is divided into several sections:

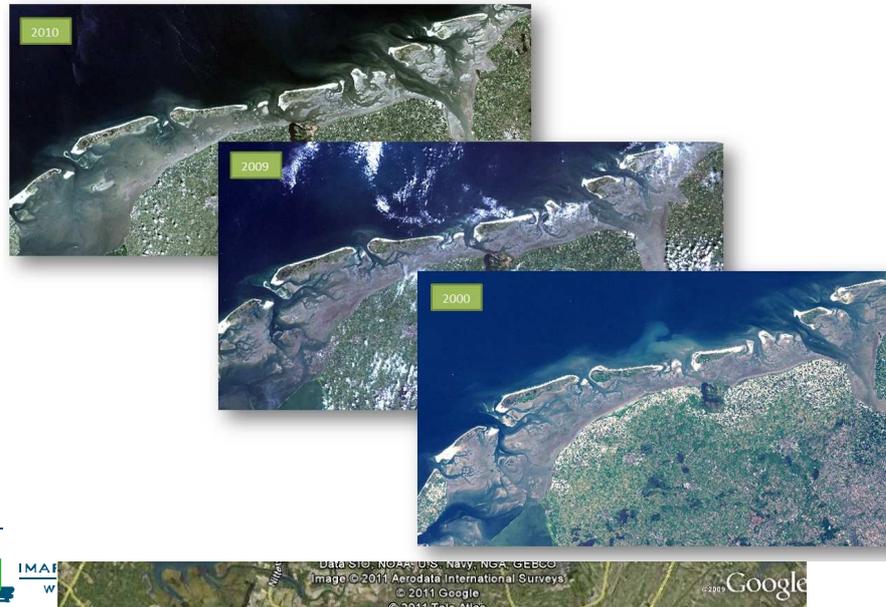
- Data Access:**
 - Data Distribution Status:** All systems nominal (SeaWiFS mission ended December 2010). NOTE: FTP connections must be made in PASSIVE mode.
 - Level 1 and 2 Browser:** Visually search the ocean color data archive. Directly download or order data from a single file to an entire mission. Simulated data from the upcoming Aquarius mission can be found here.
 - Level 3 Browser:** Browse the entire global ocean color, sea surface temperature and sea surface salinity data sets for many parameters and time periods and download PNG images or digital data in HDF format.
 - Global Time Series:** Time series plots of selected SeaWiFS, MODIS and OCTS Standard Mapped Images for a set of selected regions or the entire globe.
- Support Services:**
 - SeaDAS:** A comprehensive image analysis package for the processing, display, analysis, and quality control of ocean color data.
 - SeaBASS:** An archive of in situ oceanographic and atmospheric data for use in algorithm development and satellite data product validation.
 - Registration for support services:**
 - o Data access and Subscriptions
 - o Forgotten password
 - o Email change
 - o SeaWiFS Access Authorization
 - Near Real-Time (NRT) Services:**
 - o NRT Data Subscriptions

Aspects of Remote Sensing for coastal defence issues around Rottum, Dutch Wadden Sea (under completion)

- Main objective of the project is to link scientific literature, data and satellite data analysis and to map emerging tidal flats, channel morphology and sediment characteristics in the eastern Dutch Wadden Sea (Rottum Island area), in relation to coastal defence issues.



Study area- Rottum, Dutch Wadden Sea



Research questions:

- What methods are available to map emerging tidal flats using historical satellite data ?
- What is the applicability of these methods to map tidal flats in the Dutch Wadden Sea ?
- Can results be used for coastal defence issues ?
- What future steps can be proposed to use Remote Sensing in coastal defence strategies ?

■ The materials:

- Landsat, ASTER, ERS data, sediments measurements data, scientific literature on Wadden Sea and Remote Sensing data processing methods
- Remote Sensing techniques (Brockmann Consult) for mapping the shape of emerging tidal flats, mussel and oyster beds and for determining sediment characteristics

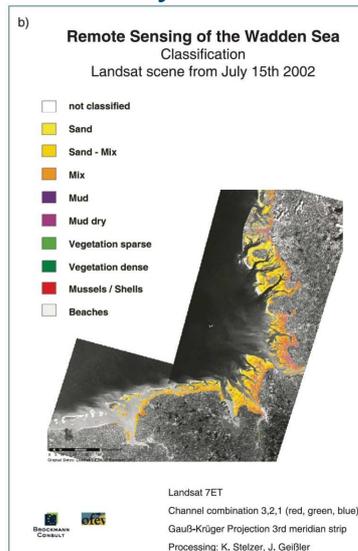
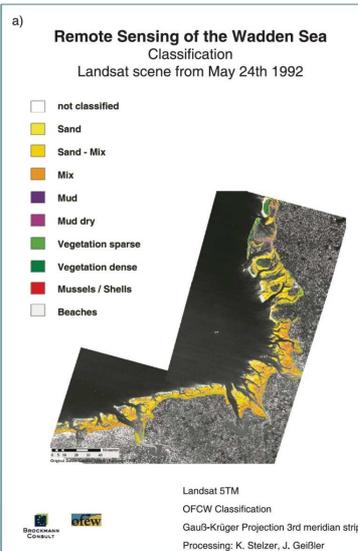
■ The methods:

- Testing Brockmann Consult classification methods in Rottum Island area in the Dutch Wadden Sea
- Validation using sediment measurements data
- Analysing broader applicability in the Dutch Wadden Sea of the used methodology
- Linking results to coastal defence issues and further developments

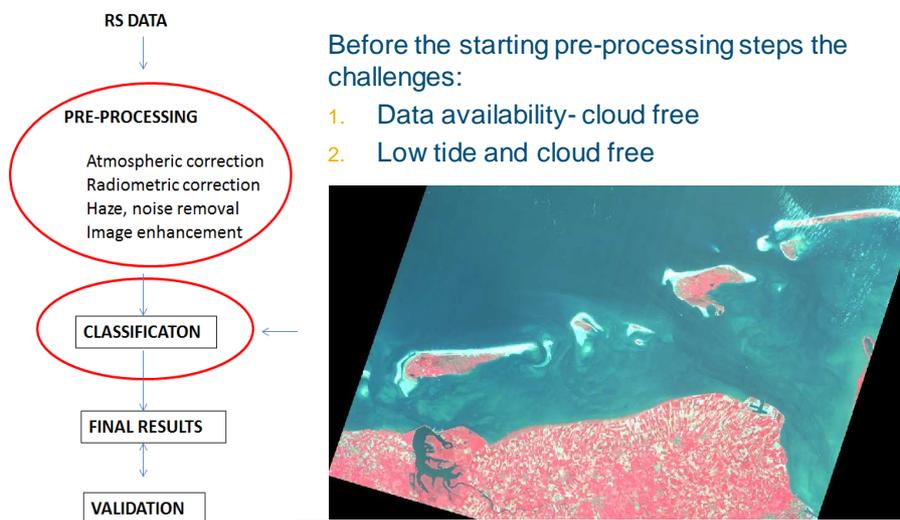


Experience of sediments mapping-

Brockmann consult, Germany



The steps:



Cloud free- but high tide. Problems with recent Landsat 7 series, failure of the sensor

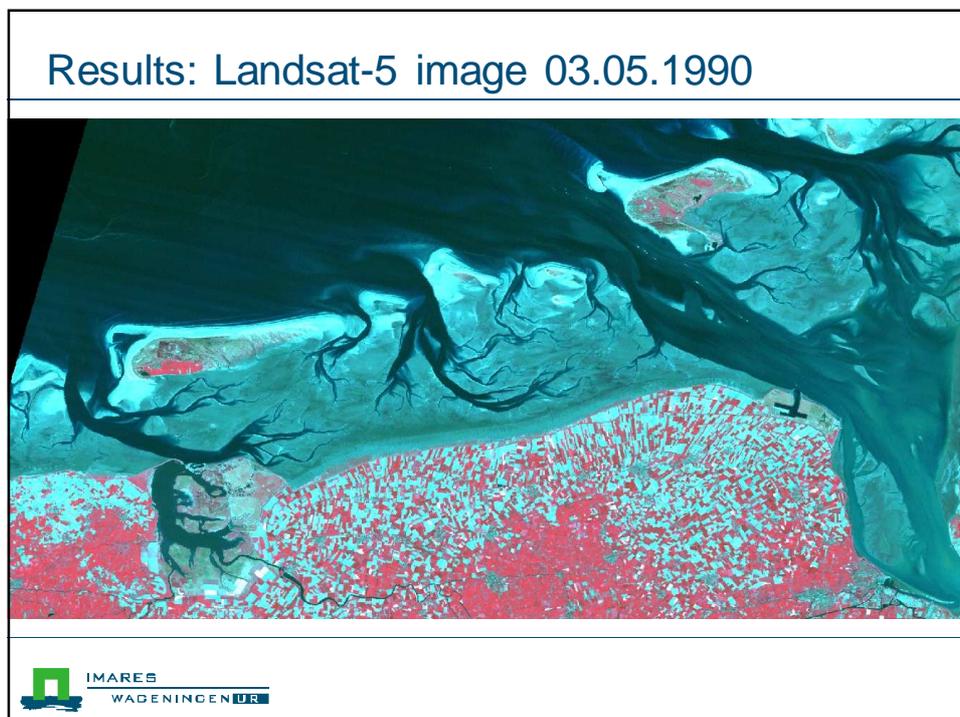
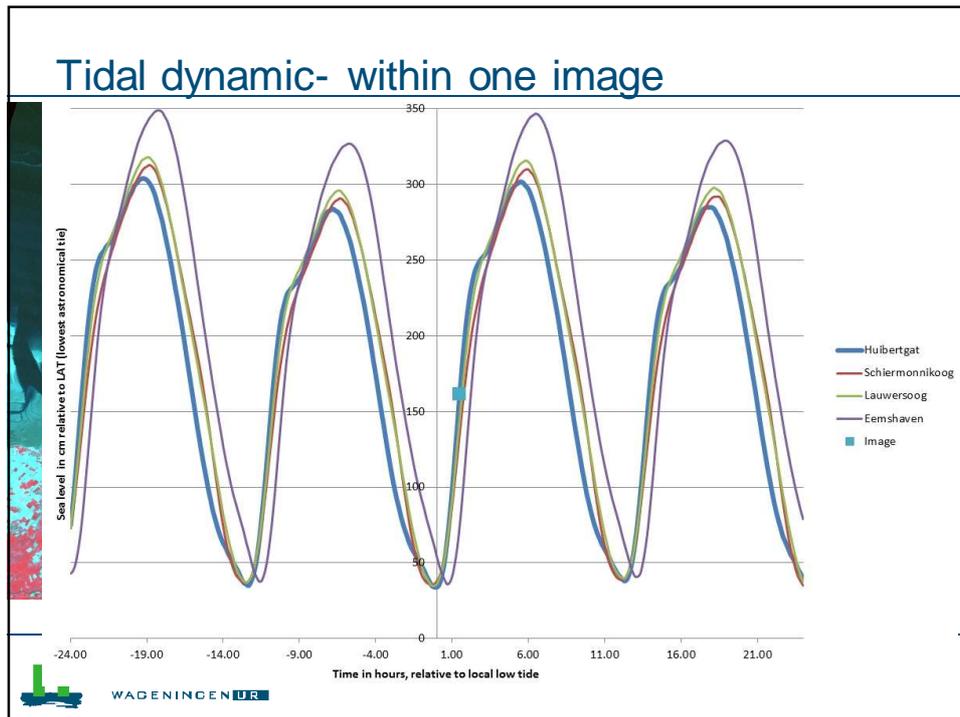


Landsat-5 still functioning good, date- 04.07.2010



Landsat- 5, date- 01.02.2009





Pre-processing- Atmospheric correction

The parameters as input to atmospheric corrections for each band.

- Time, date of acquisition, sun elevation; correction for each band- offset gain; azimuth of illumination and recorded by sensor

Wadden Sea area- mainly imaged in the morning- 10-11.30 am

Band	DNmin	S. Elev.	1%	H Lmin	L1%	Lhaze	(Lmax-Lmin)/255	L. Min	L. Max	S-E Dist.	S. Exo.	S. Elev.
1	61.23	42.65	0.01	3.5382071	0.2848222	3.2533848	0.0602353	-0.15	15.21	1.002	195.70	42.6516155
2	29.11	42.65	0.01	3.1401396	0.2661931	2.8739465	0.1174902	-0.28	29.68	1.002	182.90	42.6516155
3	27.10	42.65	0.01	2.0639412	0.2266061	1.8373350	0.0805882	-0.12	20.43	1.002	155.70	42.6516155
4	48.18	42.65	0.01	3.7743082	0.1523806	3.6219276	0.0814510	-0.15	20.62	1.002	104.70	42.6516155
5	73.28	42.65	0.01	0.7549987	0.0319170	0.7230818	0.0108078	-0.037	2.719	1.002	21.93	42.6516155
7	28.10	42.65	0.01	0.1451149	0.0108457	0.1342692	0.0056980	-0.015	1.438	1.002	7.45	42.6516155

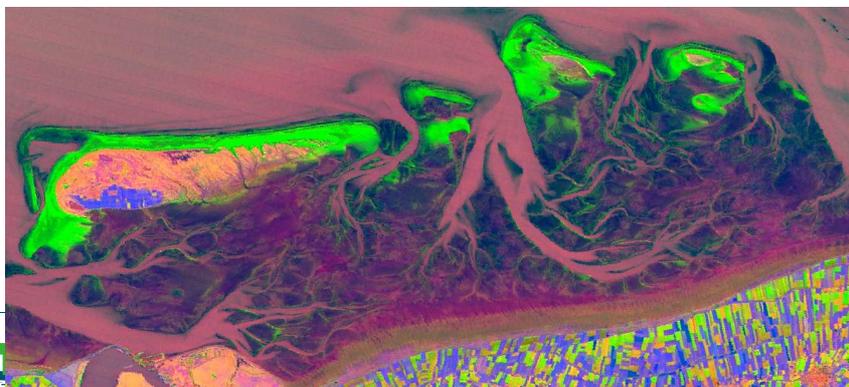


Pre-processing

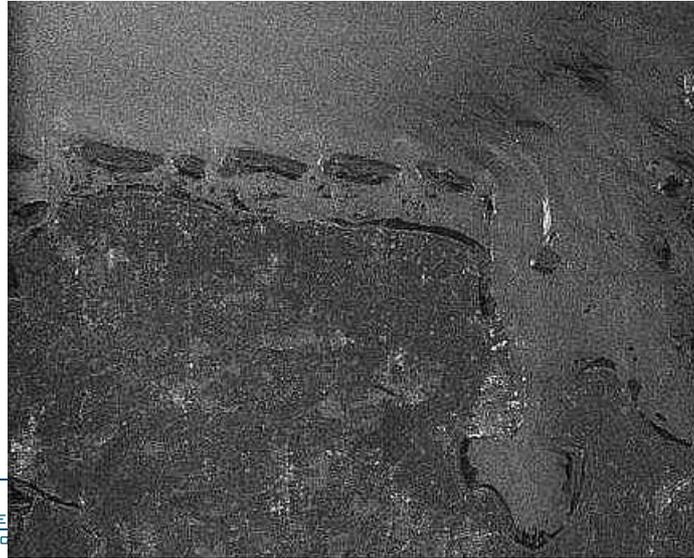
-Dark pixel subtraction- too "much" water

-Band ratio- Blue (water band) over land; NDVI- Normalized vegetation index; PCA- Principal Component Analysis, etc

Basically deriving all possible information as input to classification

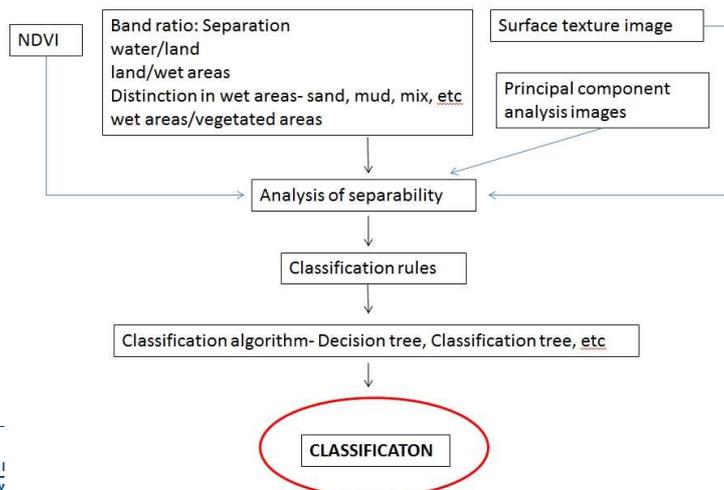


Data fusion- radar data for texture, ERS-1 (15 meters)- 2000

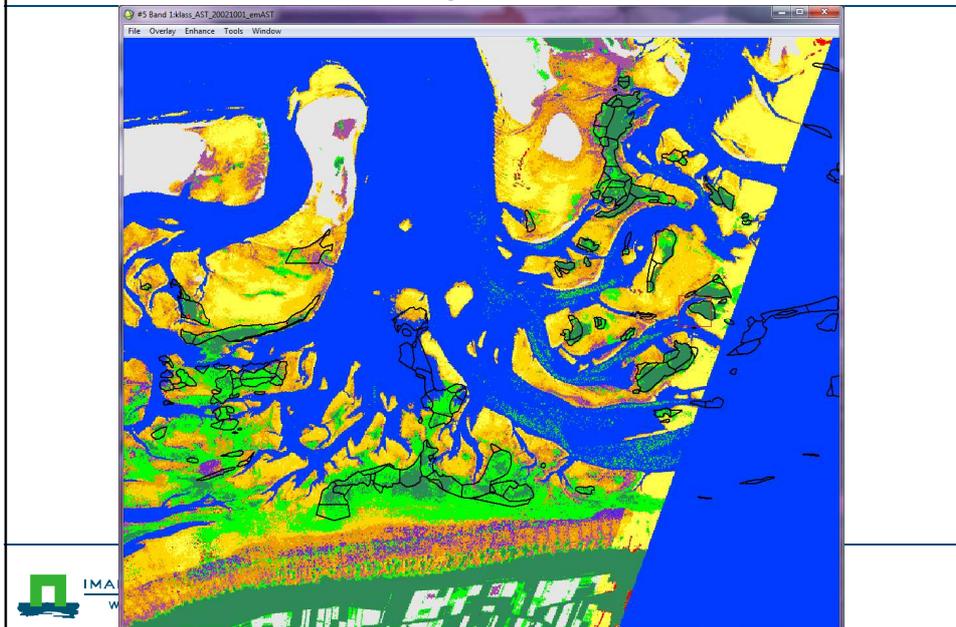


Classification- decision tree

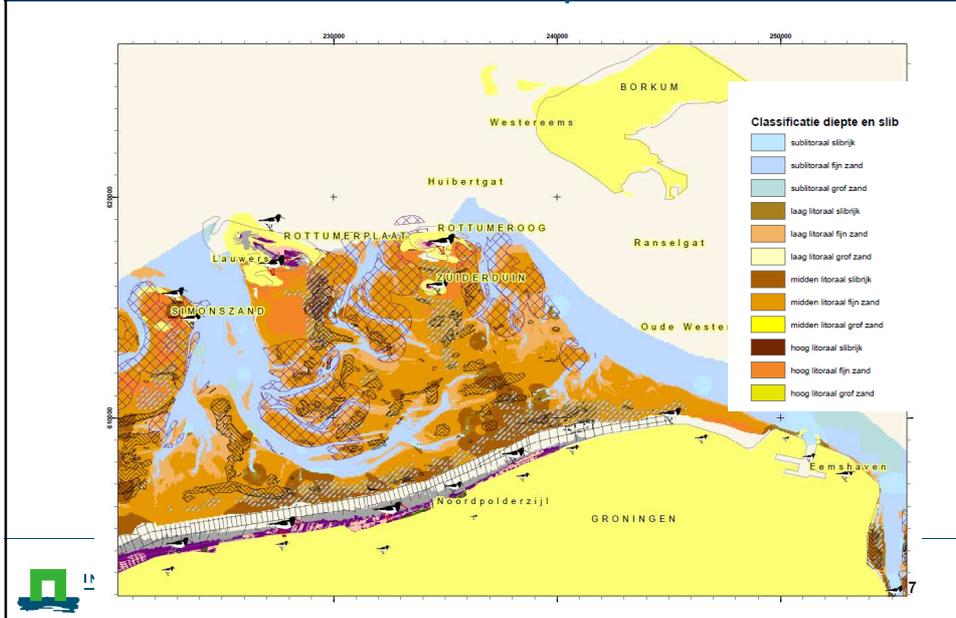
- Decision tree- building parameters and rules, using as input different images.



Results: Landsat image 03.05.1990



Wadden zea atlas- for comparison



Conclusion

Remote sensing methods:

- The classification had a fairly good match with sediment data from the field
- The extension of the applied methods to larger areas in the Dutch Wadden Sea is possible
- Limited availability of low tide and cloud-free satellite data

Coastal defence issues:

- Uncertainties in long-term trends in climate change

Future steps 2012:

- Validation of Remote Sensing images from Ameland and Rottum tidal areas
- Translation of Remote Sensing techniques into long-term climate change scenario studies and evaluation of possible coastal defence strategies



Possible application for stock assessments

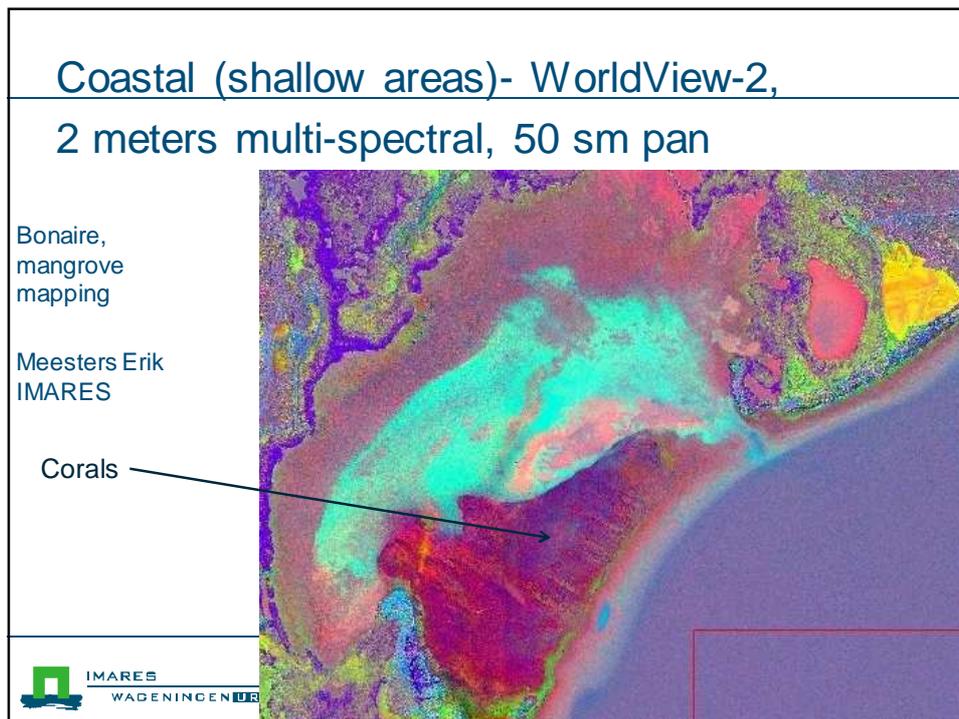
From implemented study:

- Estimation of mussel/oysters beds location, area (size) with field truth to verify
- Derive the spectral signature- to identify the features- density, structure, type (sediments)
- Additional tool for sampling

New applications:

- Primary production- chlorophyll- relation to habitat
- New generation of satellites coming- Sentinel, launch next year 2012; http://www.esa.int/esaLP/SEMZHM0DU8E_LPgmes_0.html
15 meters resolution, land and water applications, data free





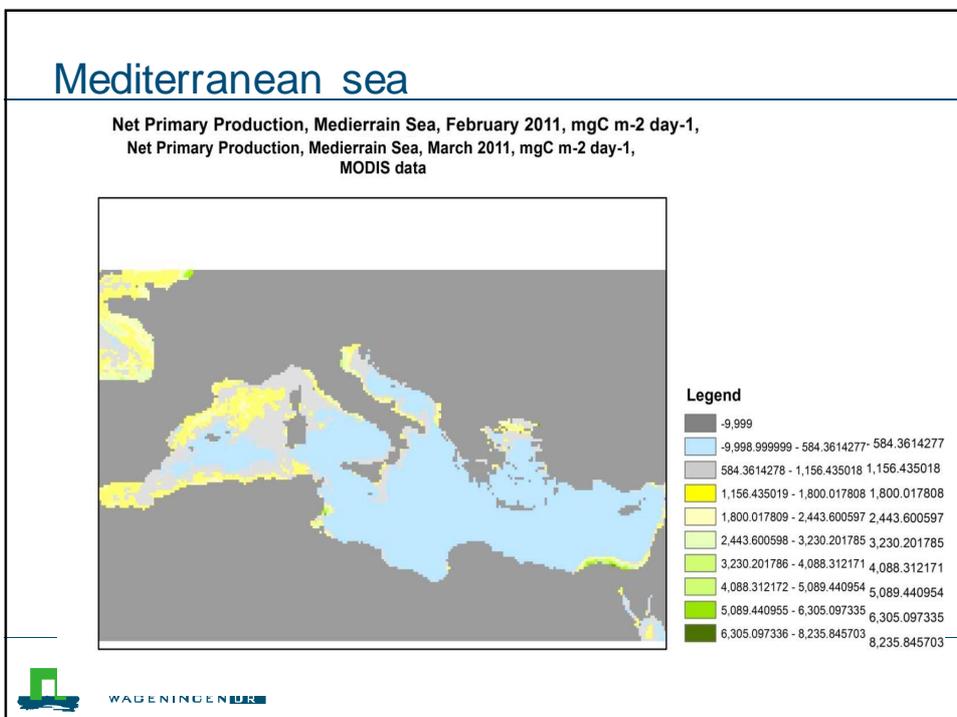
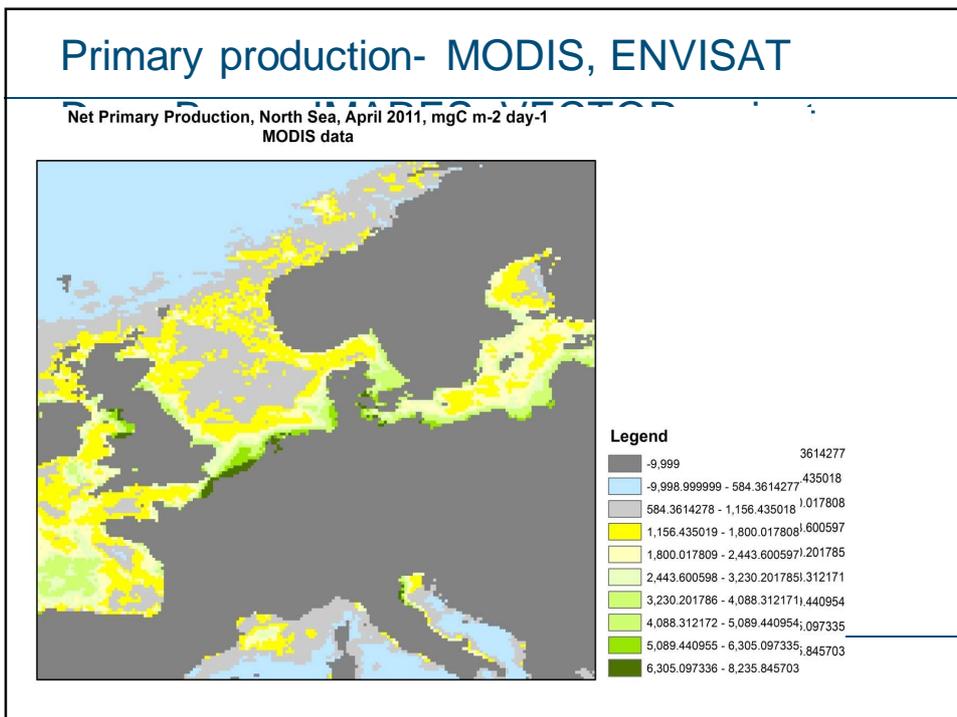
■ Primary production- chlorophyll- relation to habitat

The Net Primary production (NPP) is a function of:

- chlorophyll,
- available light,
- photosynthetic efficiency.

The NPP is computed as monthly and annual average and can be downloaded for every world region.

The NPP is expressed in $\text{mgC m}^{-2} \text{ day}^{-1}$



Thank you for your attention
Questions?



Assessment of Sea Scallops (*Placopecten magellanicus*) in US waters

Dvora Hart

Northeast Fisheries Science Center

Woods Hole MA 02543

Most valuable fisheries in Northeast US in 2010

Invertebrate fisheries make up over 75% of the total value of fisheries in the Northeast US

The two most valuable fisheries in the entire US are for sea scallops and American lobsters

Accurate assessment of these valuable stocks is essential

Fishery	Ex-vessel value (millions US\$)
Sea scallop*	451
American lobster*	401
Blue crabs*	141
Atlantic salmon	77
Menhaden	40
Hard clam* (<i>Mercenaria</i>)	36
Surf clam*	30
Atlantic cod	28
Summer flounder	27
Ocean quahog*	23
Haddock	22
Striped Bass	21
Soft clam*	20
Goosefish	19
Atlantic herring	18
Eastern oyster*	16
<i>Loligo</i> squid*	16
<i>Illex</i> squid*	11
Silver Hake	11
*Invertebrate	

Outline

Introduction

Overview of management history

Survey methods

Assessment modeling

Atlantic sea scallop (*Placopecten magellanicus*)

Fairly long lived ($M \sim 0.15$), separate sexes

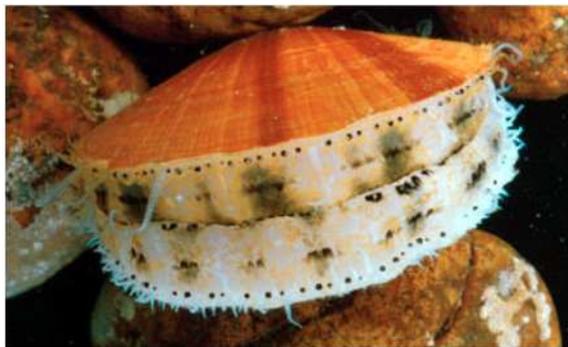
Good swimmers when young, round side is *up*

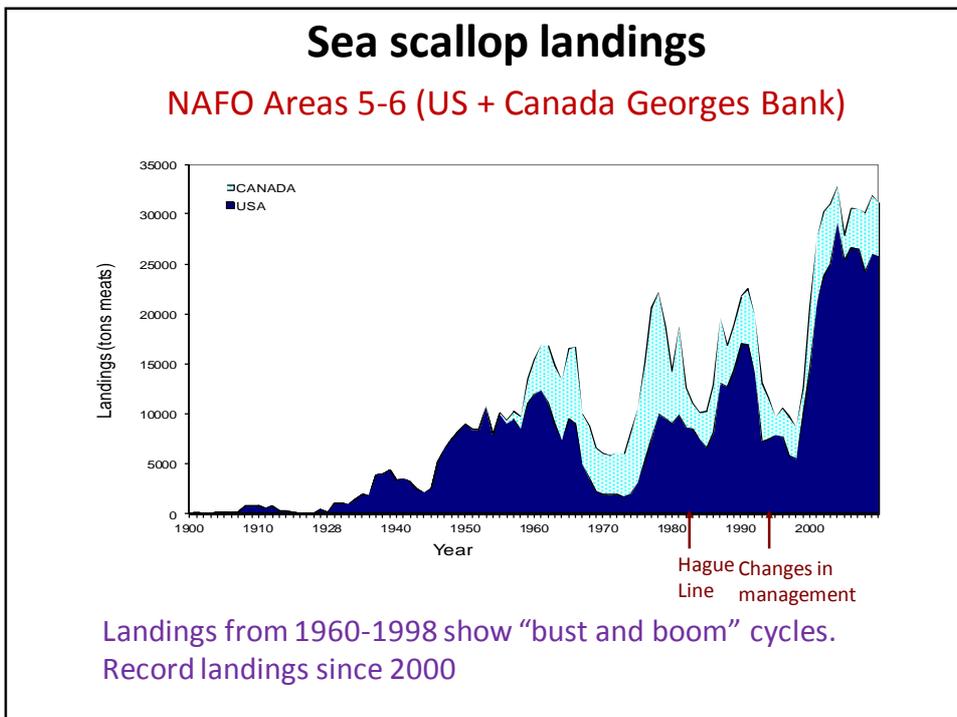
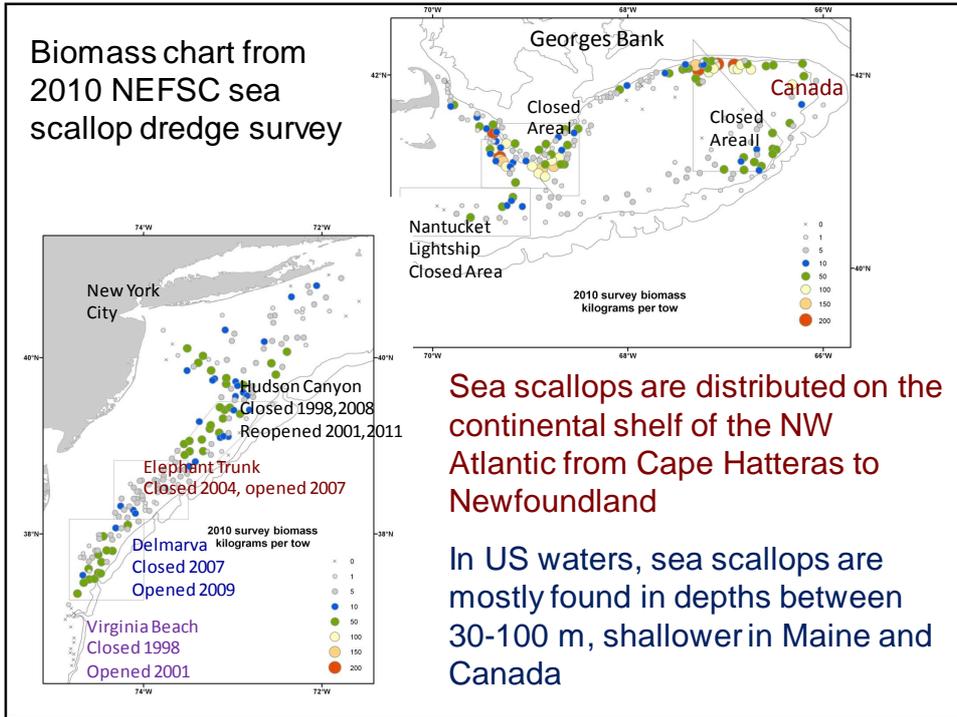
Currently recruit to fishery at age 4-5 (~20 g meat),

Historically, some 3 year olds were fished (~10-15 g meat)

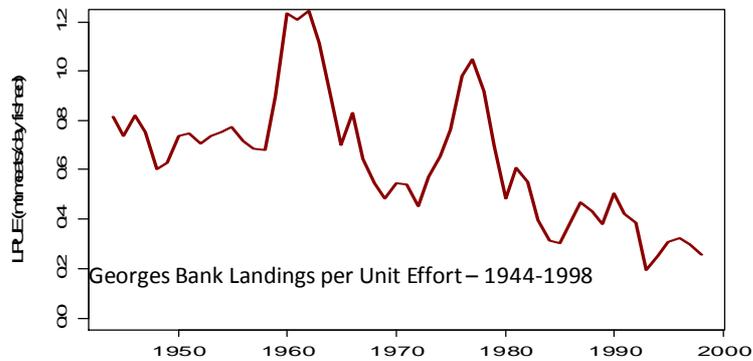
Mean maximum shell height approx 14cm

Largest scallop observed in US survey was 19 cm, >200 g meat



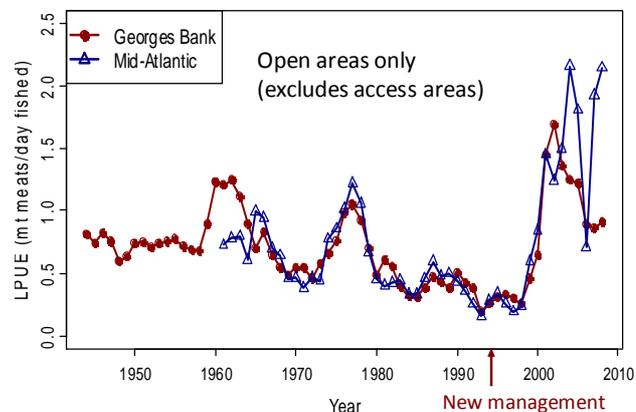


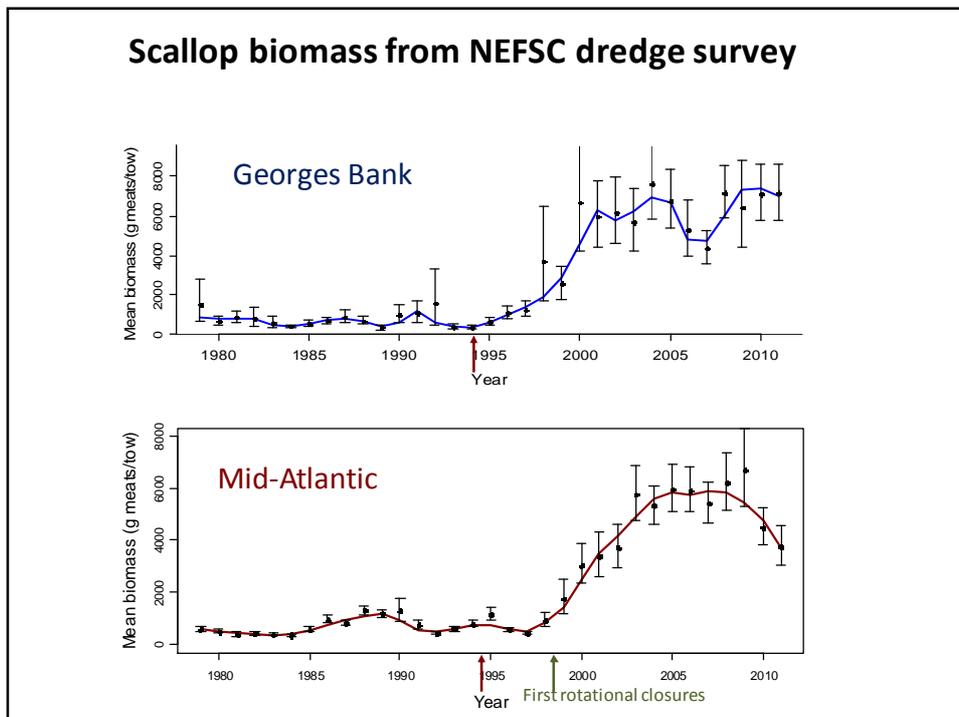
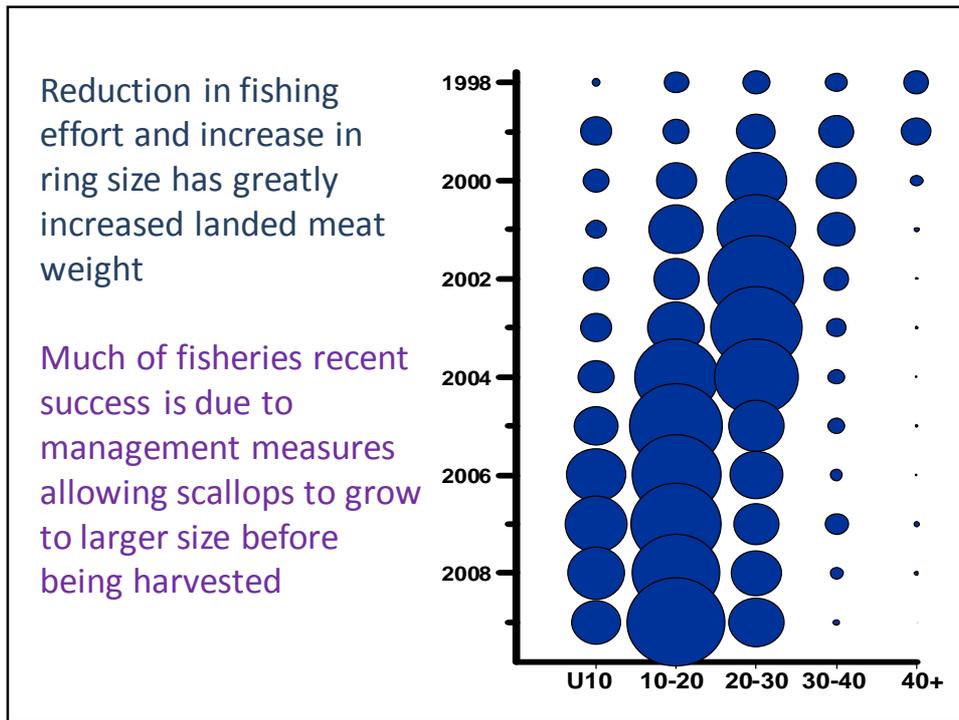
Catch per day fished (approximately proportion to exploitable biomass) Georges Bank, 1944-1998

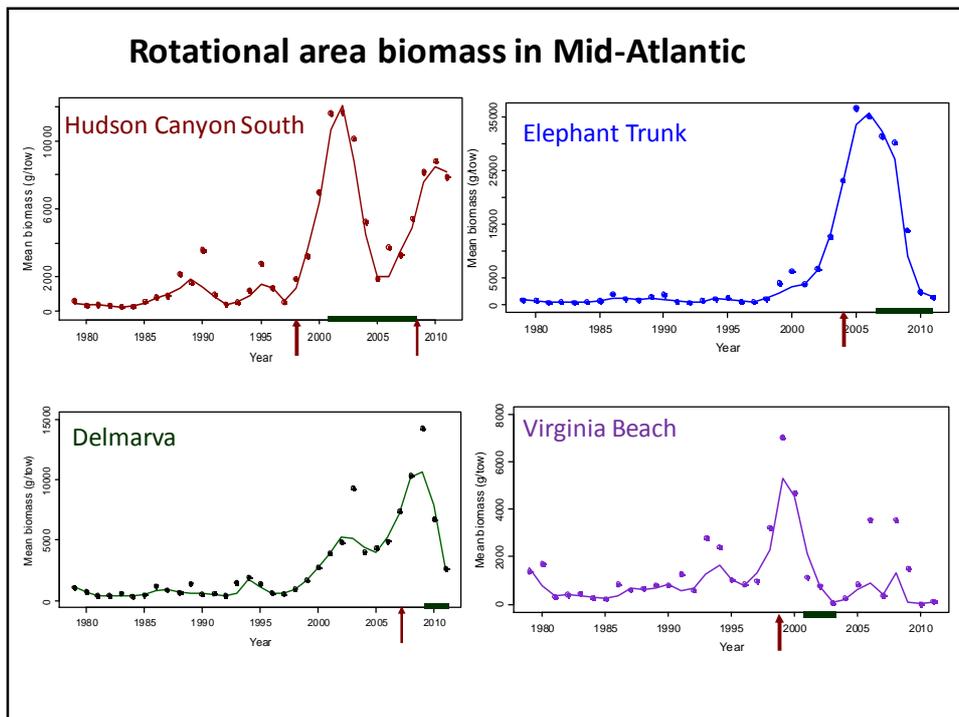
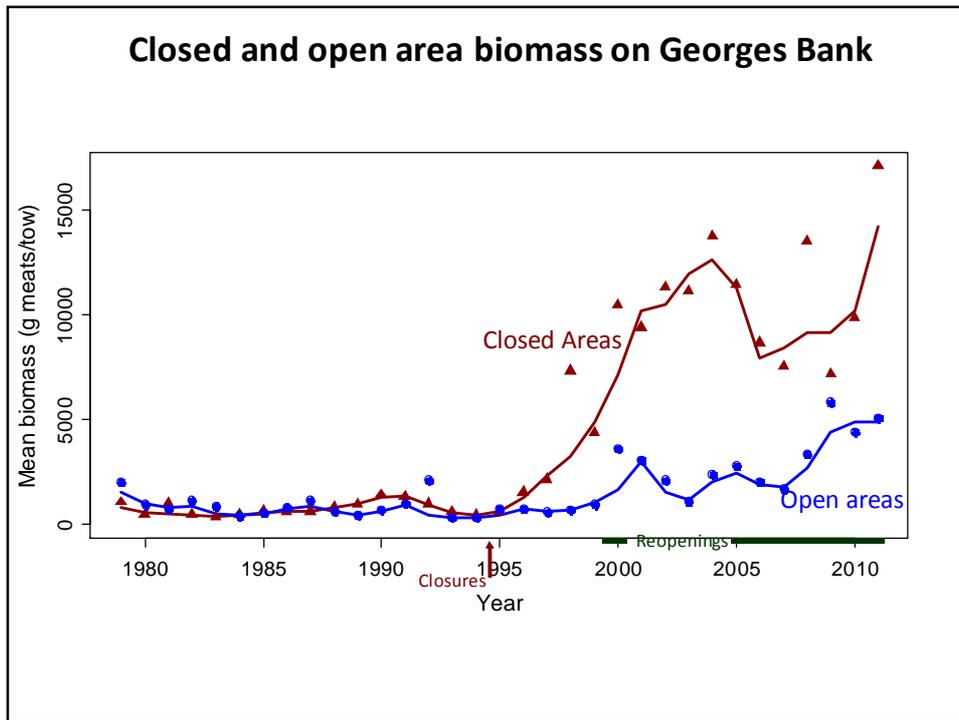


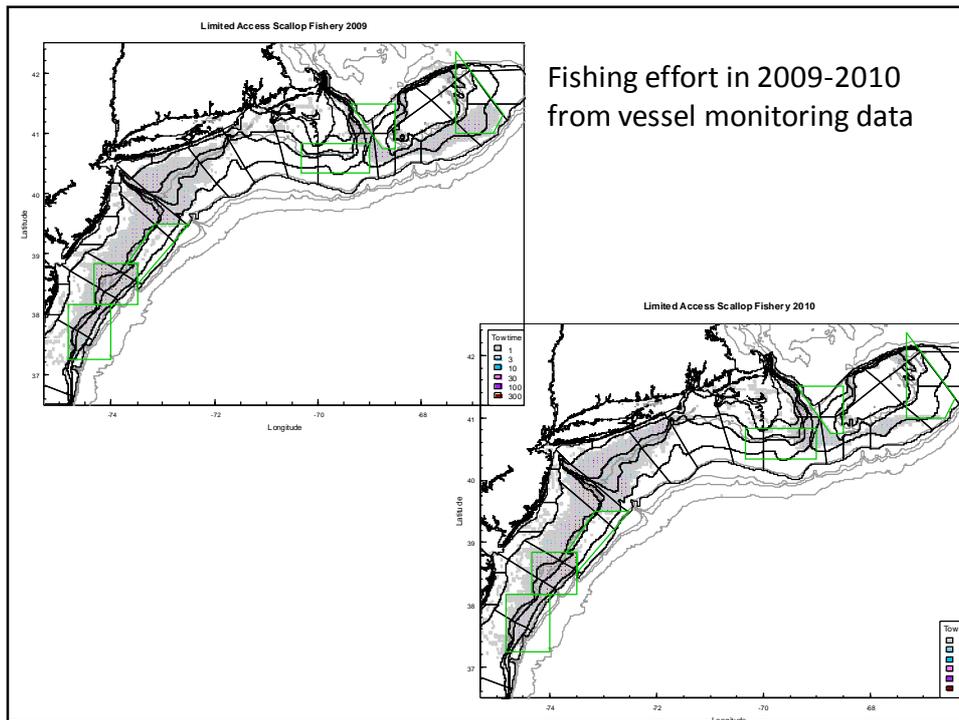
Long-term decline in catch rates due to “ratcheting-up” of fishing effort

New management measures were implemented between 1994-2005 that allowed only ~350 vessels to fish for scallops (except small “day boat” fishery) and restricted the days that these vessels could fish. Gear regulations gradually increased ring size from 76 mm in 1994 to 102 mm since 2004 and closures followed by rotational access programs were also implemented. These measures helped increase catch rates to an unprecedented level









Survey methods for sea scallops

1. Dredge survey
2. Video drop camera survey
3. Digital towed camera survey (Habcam)

NEFSC sea scallop dredge survey

Conducted annually since 1979

Uses a 2.44 m wide modified “New Bedford” (toothless) scallop dredge with 51mm rings and 38 mm plastic liner, towed for 15 min on bottom

Stratified random design
~400-500 stations/year



Dredge survey

Advantages

Long time series

Gives reasonably accurate index of abundance

Obtains physical samples for ageing, meat weights,
accurate shell height measurements

Disadvantages

Labor intensive, especially as abundance has
increased

No direct estimate of absolute abundance

Reflects average conditions along tow path – no
finer scale information

No in situ information

The dredge survey is labor intensive, especially since the recent increases in abundance



Dredge catches give some information on bottom type and “habitat”, but quantifying this is difficult



Video drop camera survey (U Massachusetts)

Grid design, 4 drops per grid

Main camera gives view of $\sim 2.8 \text{ m}^2$



Video drop camera survey

Advantages

Gives absolute abundances

In situ habitat information

Disadvantages

Limited area covered ($12 \text{ m}^2/\text{station}$ compared to $4500 \text{ m}^2/\text{station}$ for dredge survey)

Shell height measurements have considerable error

No physical samples

Fine scale (2.8 m^2) but no mesoscale information (typically 5.5 km between stations)

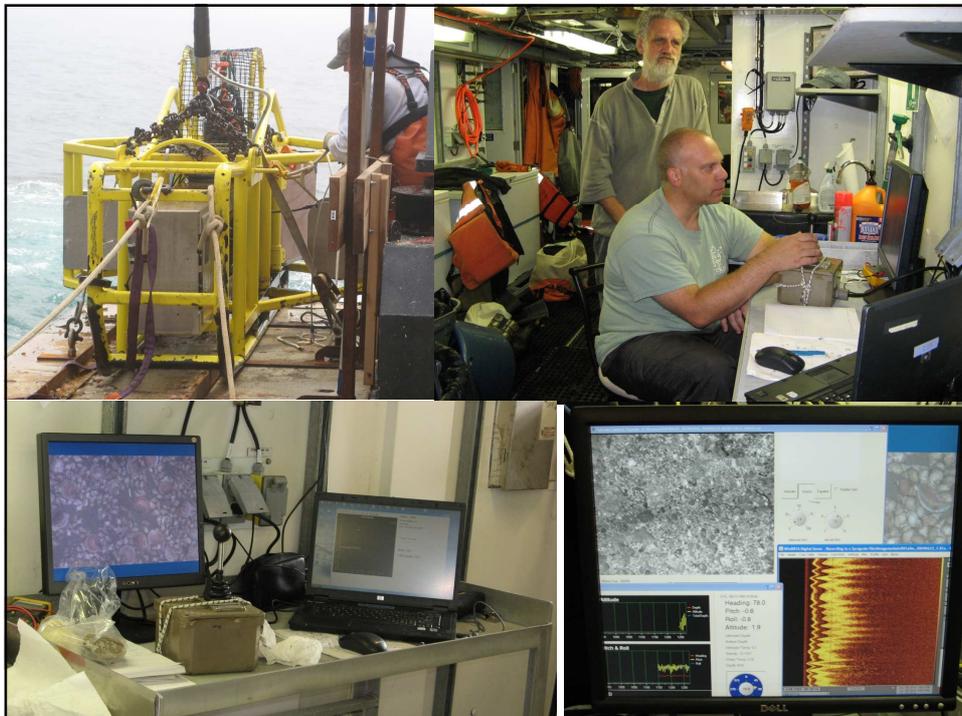
“Habcam” towed digital camera survey

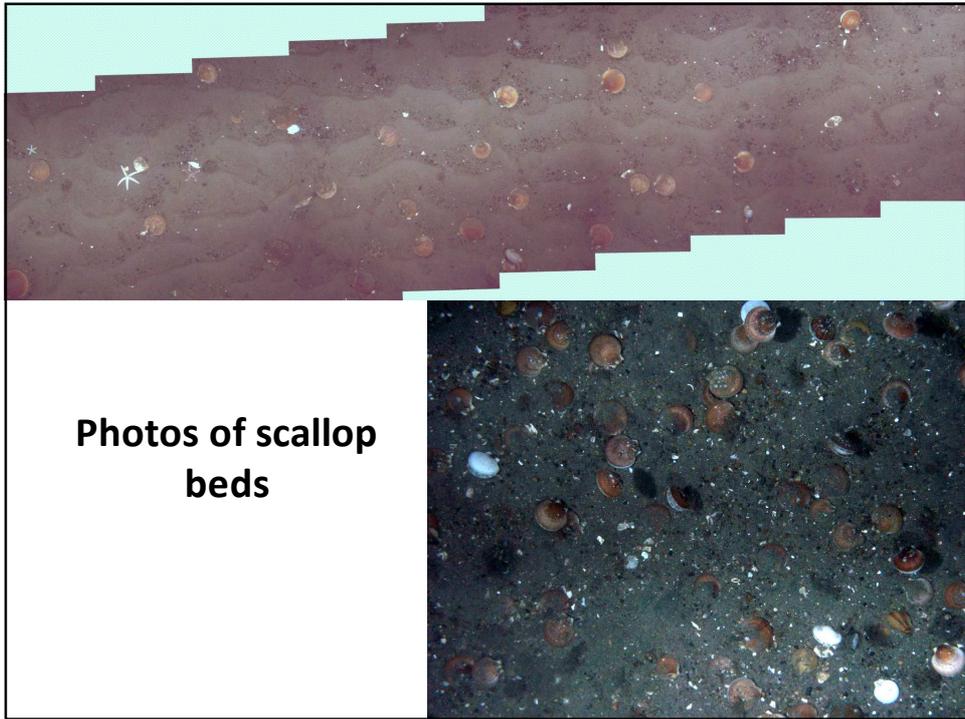
Towed ~ 2 m off the bottom @ 9 km/hr using fiber-optic cable

Digital camera synched with 4 strobes inside protective frame

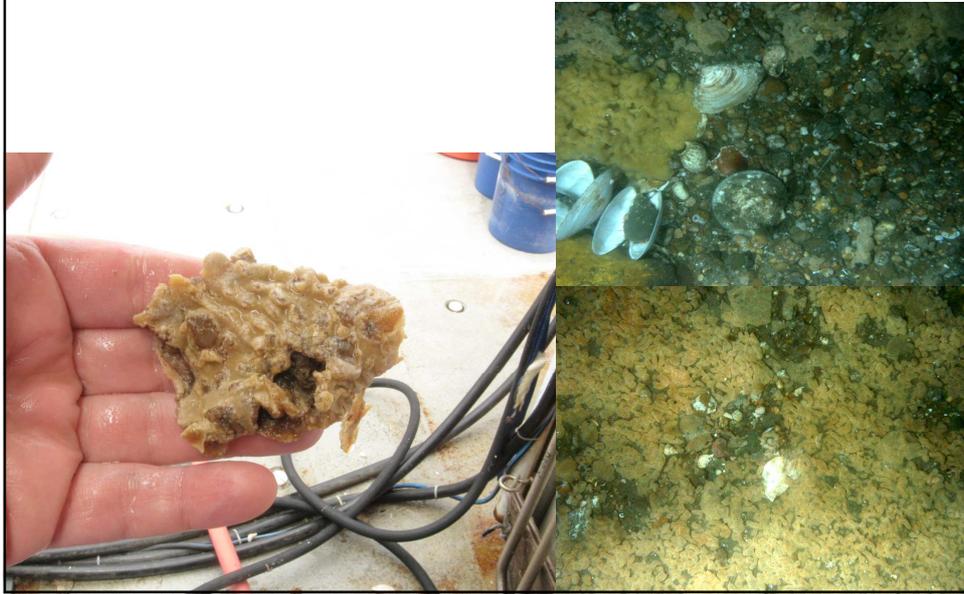
Takes several photos per sec for overlapping images

Other instruments include altimeter, CTD, side-scan sonar, fluorometer

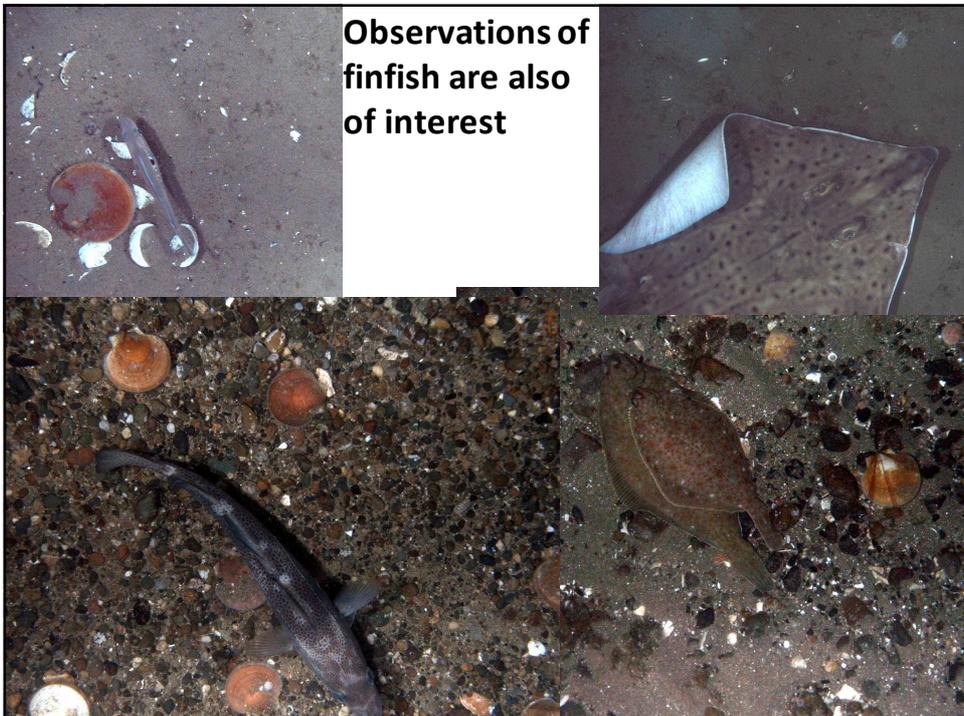


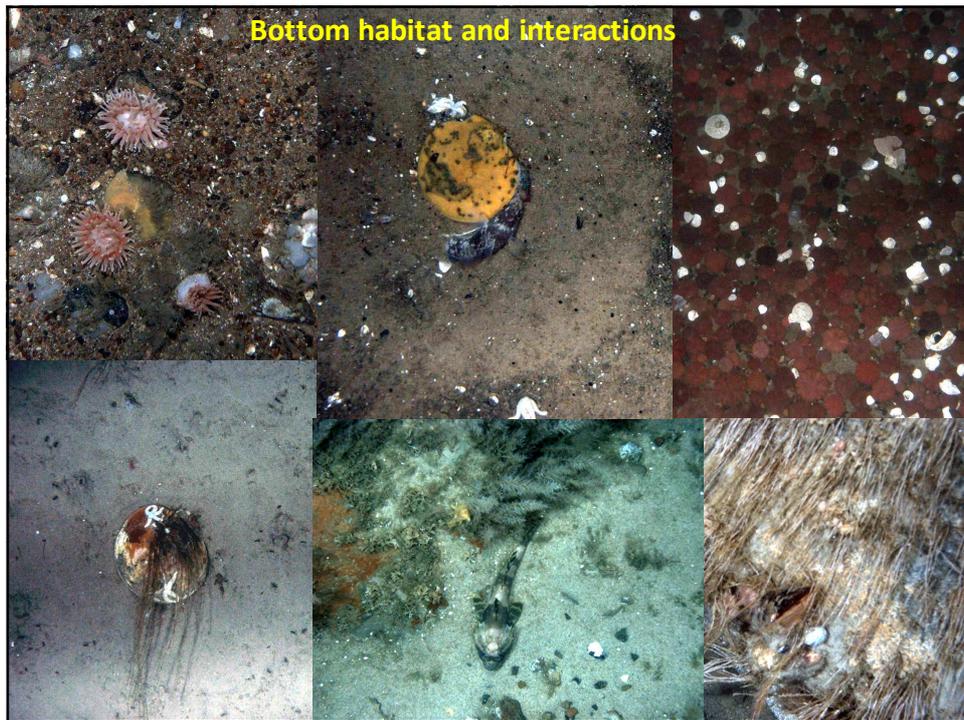


Observations of the invasive tunicate *Didemnum*



Observations of finfish are also of interest





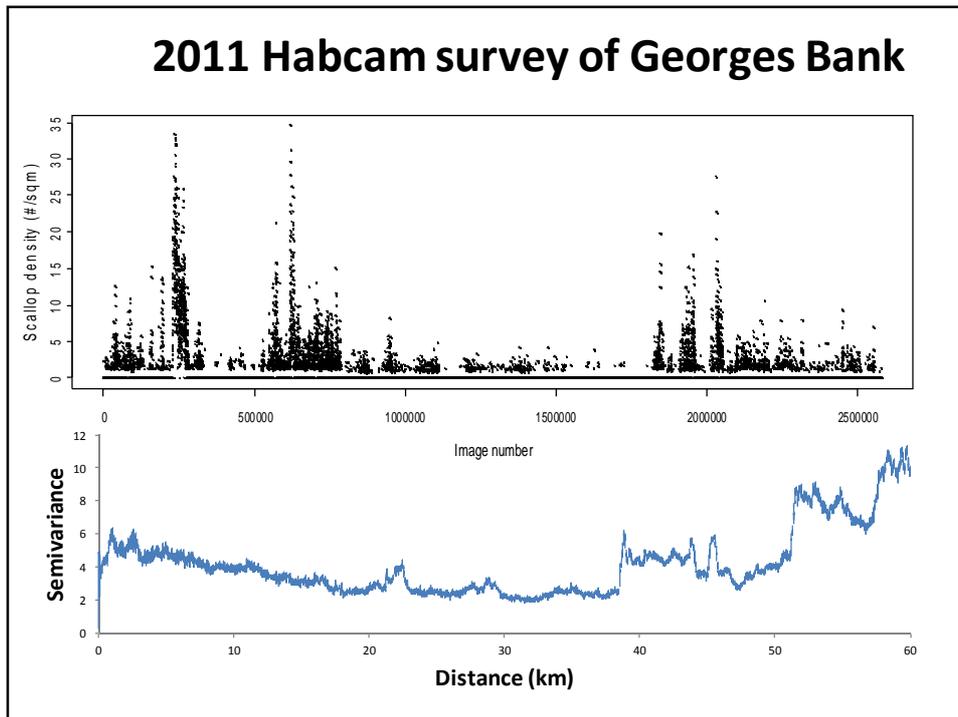
Towed digital camera survey

Advantages

- Gives absolute abundances
- In situ habitat information
- Covers large areas at all scales

Disadvantages

- No physical samples
- Relatively expensive startup costs
- Requires labor-intensive photo analysis (though automated image analysis is being developed)
- Need to use geostatistical model-based estimation rather than simple designed-based estimates



Stock Assessment Models

All size-based with stochastic growth

Estimation model (CASA)

Forecasting model (SAMS)

Area specific (16 areas presently) to account for area management and spatial structure
Used for setting fishery specifications

Reference point model (SYM)

Estimation of MSY, FMSY, BMSY

CASA analytical stock assessment model

Statistical catch at size model (similar to SCAA models used for finfish assessments)

Based on Sullivan et al. 1990 (CJFAS 47:184-198)

Uses data on survey trends, shell height distributions, commercial landings, commercial shell heights, and growth data to fit the model

Implemented in AD Model Builder

Appropriate for sea scallops (abundant commercial and population shell height data, growth increment data)

Stochastic growth matrices used by CASA

Based directly (non-parametrically) on shell increment data or via von Bertalanffy growth equations with random effects (variability among individuals)

	43	48	53	58	63	68	73	78	83	88	93	98	103	108	113	118	123	128	133	138	143
43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
53	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
58	0.05	0.02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
63	0.26	0.06	0.04	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
68	0.38	0.29	0.32	0.04	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
73	0.12	0.24	0.32	0.27	0.02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
78	0.16	0.25	0.2	0.46	0.34	0.02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
83	0.01	0.04	0.04	0.15	0.37	0.31	0.05	0	0	0	0	0	0	0	0	0	0	0	0	0	0
88	0	0.08	0.08	0.08	0.24	0.44	0.23	0.15	0.03	0	0	0	0	0	0	0	0	0	0	0	0
93	0	0.02	0	0	0.03	0.19	0.44	0.38	0.16	0	0	0	0	0	0	0	0	0	0	0	0
98	0	0	0	0	0	0.05	0.25	0.35	0.43	0.32	0.04	0.01	0	0	0	0	0	0	0	0	0
103	0	0	0	0	0	0	0.04	0.1	0.32	0.48	0.39	0.18	0	0	0	0	0	0	0	0	0
108	0	0	0	0	0	0	0	0.01	0.05	0.19	0.39	0.48	0.3	0.02	0	0	0	0	0	0	0
113	0	0	0	0	0	0	0	0	0.02	0.01	0.18	0.25	0.56	0.43	0.02	0	0	0	0	0	0
118	0	0	0	0	0	0	0	0	0	0	0.08	0.1	0.49	0.5	0.03	0	0	0	0	0	0
123	0	0	0	0	0	0	0	0	0	0	0	0	0.03	0.05	0.45	0.72	0.02	0	0	0	0
128	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0	0.03	0.25	0.77	0.07	0	0	0
133	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.21	0.83	0.14	0	0
138	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0.86	0	0
142	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1

Sea scallop growth, estimated by shell growth increments

Last three growth lines very distinct

Fourth growth line from the shell margin (probably two year mark) is less distinct, but fairly clear

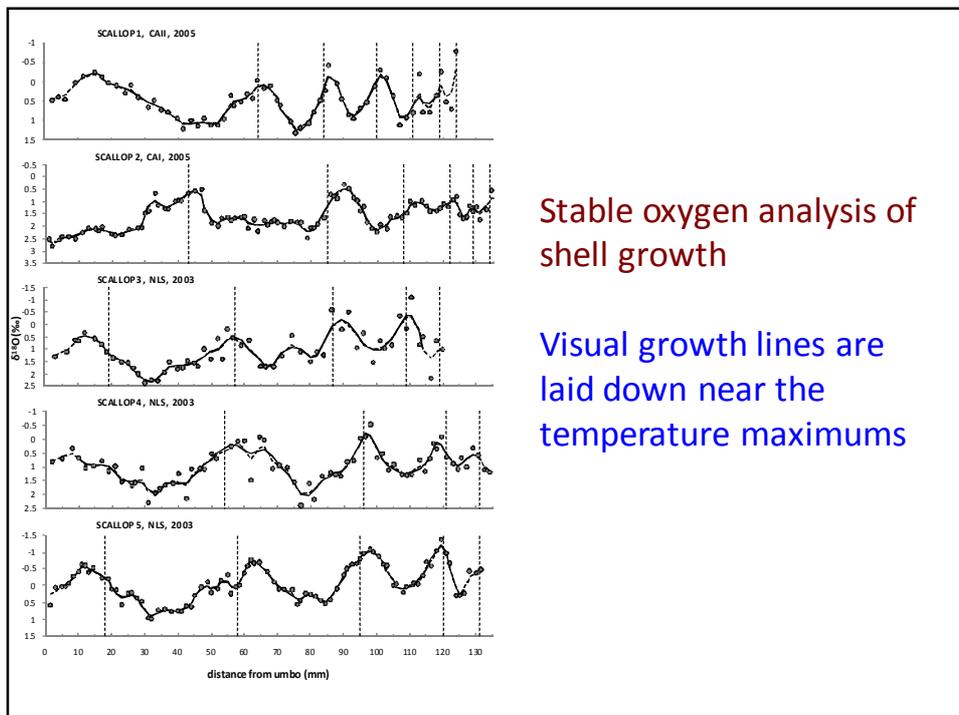
First year growth line missing

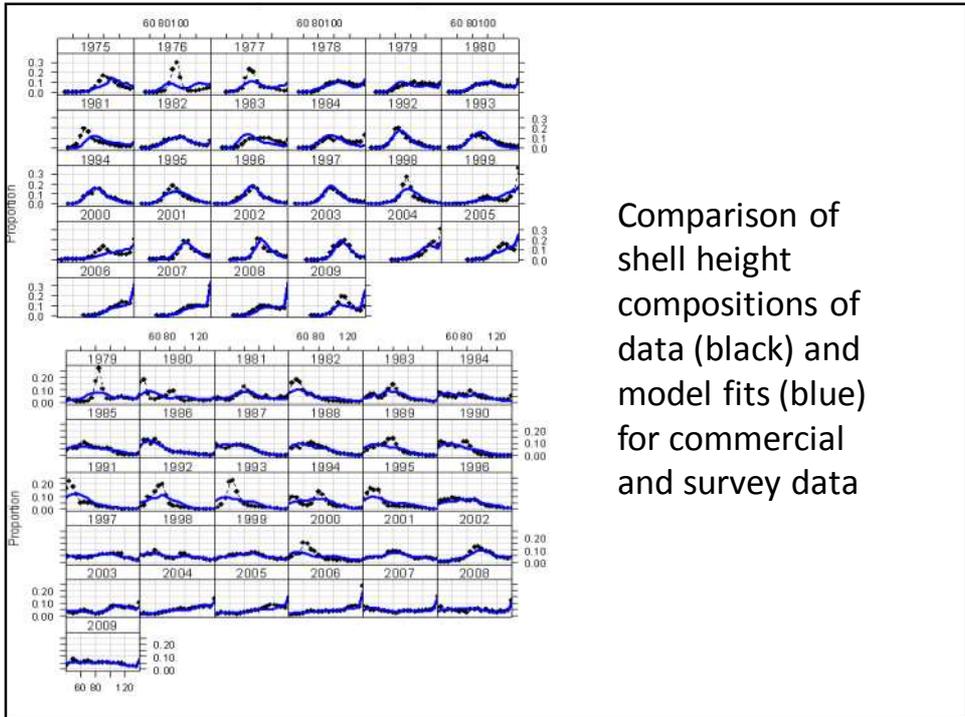


Last five growth lines distinct

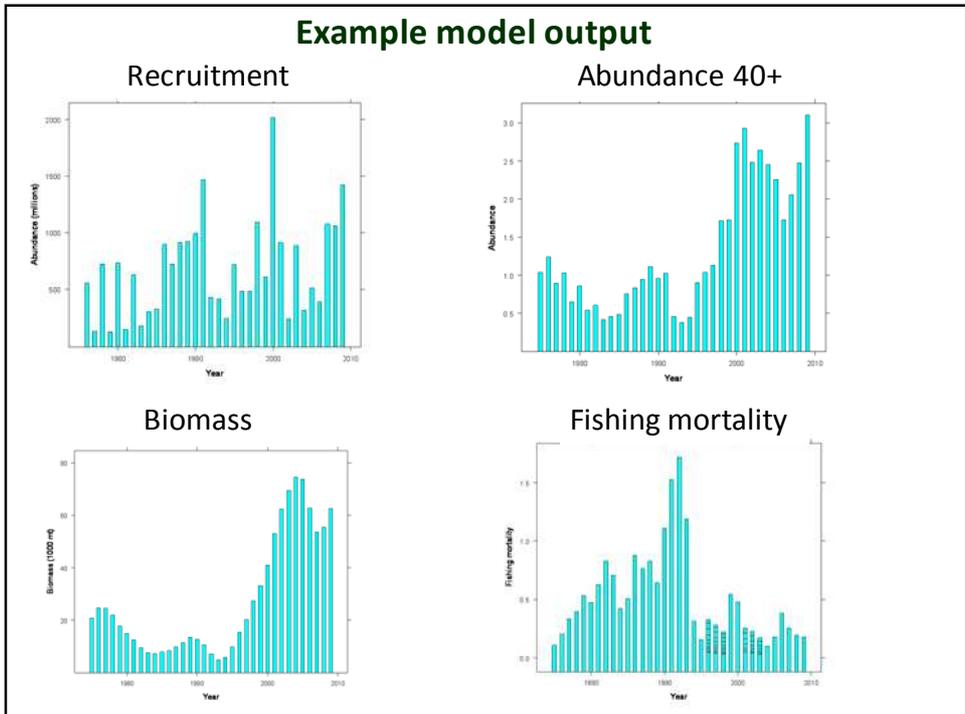
Earlier growth lines obscure or missing

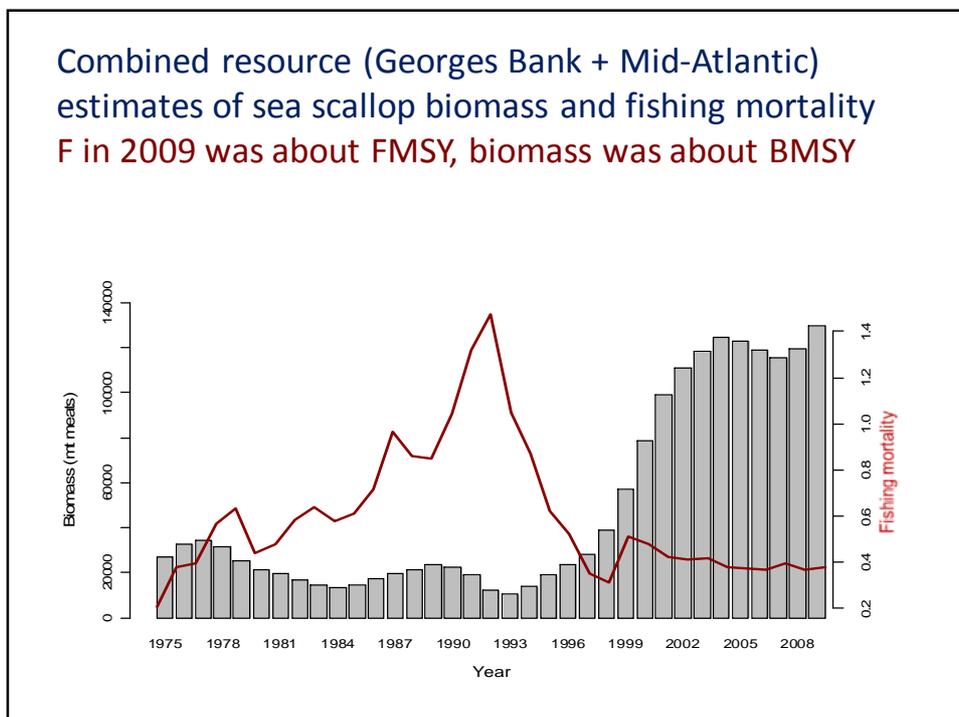
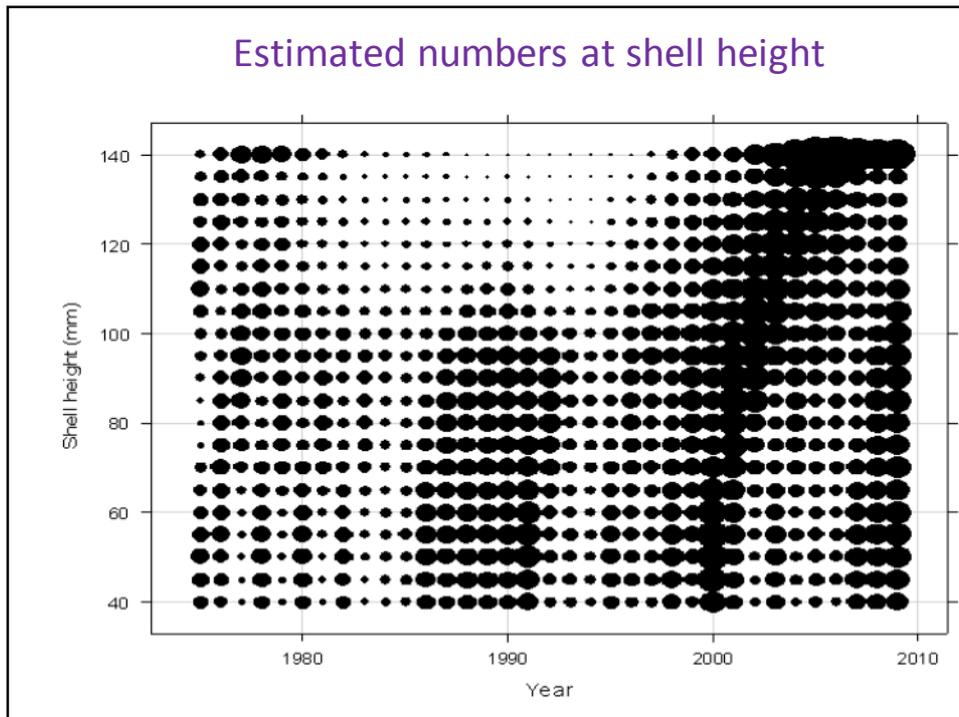
Ageing this shell is difficult or impossible, but can obtain information on growth increments starting from first visible ring





Comparison of shell height compositions of data (black) and model fits (blue) for commercial and survey data





Monitoring and modelling across borders



Eelke Folmer
 Katja Philippart
 Jaap van der Meer
 Heike Büttger
 Karin Troost
 Marnix van Stralen
 Norbert Dankers
 Jeroen Jansen
 Gerald Millat



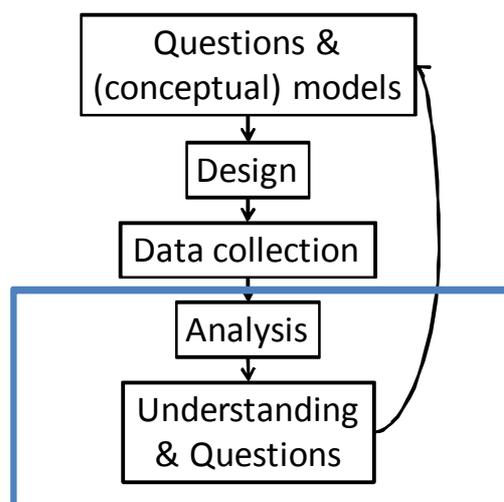
Purpose of monitoring & modelling mussels

- To know how much is there
- Understand population dynamics
 - $N_{\text{future}} = N_{\text{now}} + B - D$
- Understand the impact on other species:
 - Phytoplankton
 - Other filter feeders (competition)
 - Predators: Crabs and Oystercatchers
- Predict future stocks
 - Climate change
 - Management

Population dynamics

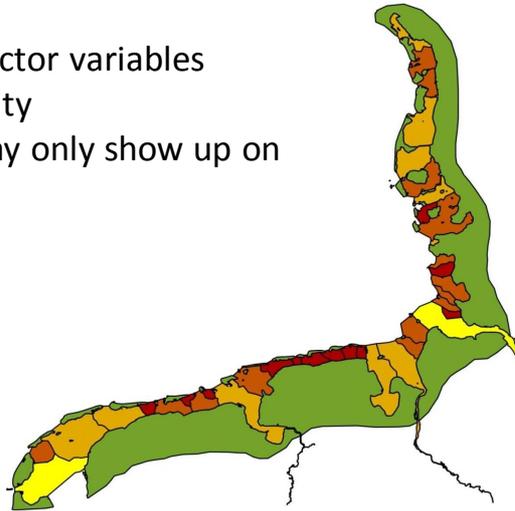
- Recruitment (Gametogenesis & Spawning)
 - Temperature
 - Food
- Settlement & survival after settlement
 - Substrate properties (habitat)
 - Disturbance (hydrodynamics)
 - Food (eutrophication, competition)
 - Predation / parasitism

Adaptive monitoring



Advantages of large scale surveys

- Much variation
 - Response and predictor variables
- Average out stochasticity
- Effects of processes may only show up on large scales
- Ecosystem modelling



Why intertidal musselbeds?

- Heterogeneity on mudflats (habitat)
- Bird food / parasites
- Consume phytoplankton (carrying capacity)
- Commercial fisheries
- High ascendancy: state of organization and stability
- History of monitoring



Spatial data

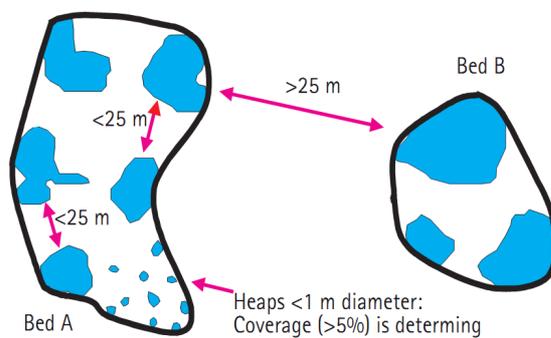
Netherlands (NL): IMARES
 Niedersachsen (NS): Nationalpark Wattenmeer NLWKN
 Schleswig-Holstein (SH): BioConsult SH (LKN-SH)
 Denmark (DK): National Institute of Aquatic Resources (Technical University of Denmark)

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
NL													
NS													
SH													
DK													

Dijkema atlas: 1969 and 1976

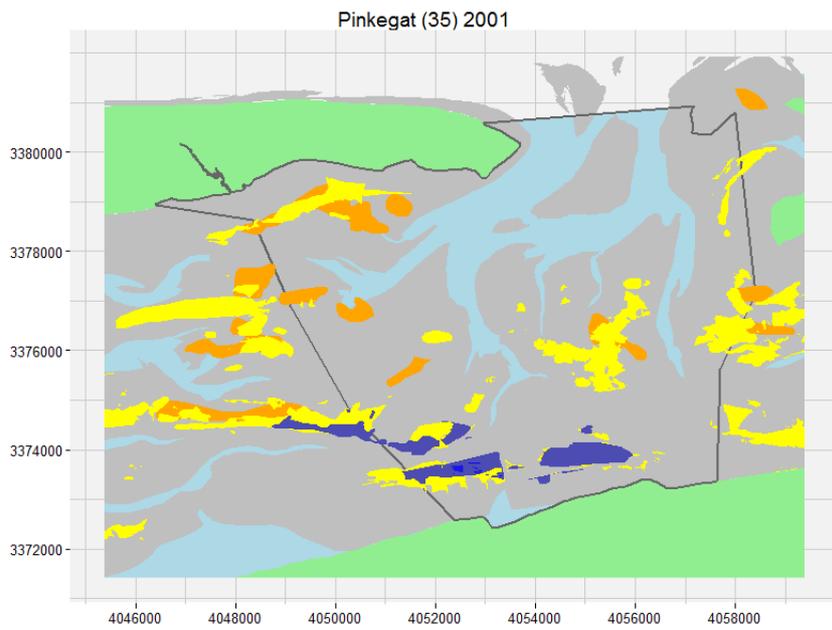
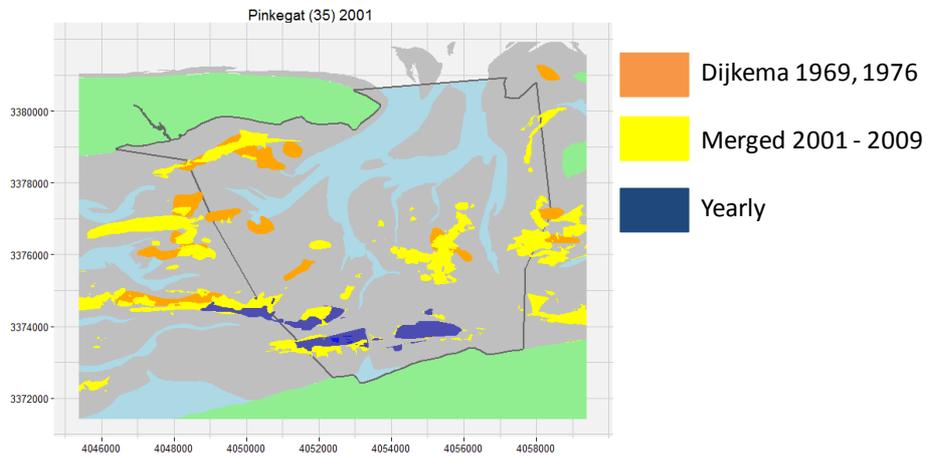
Demarcating mussel beds

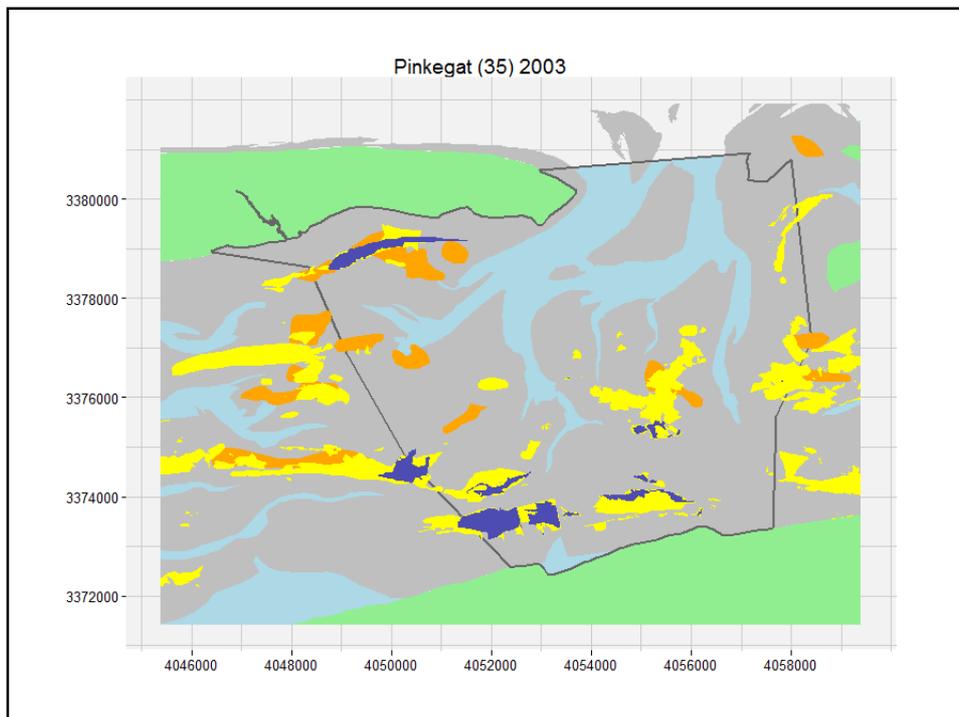
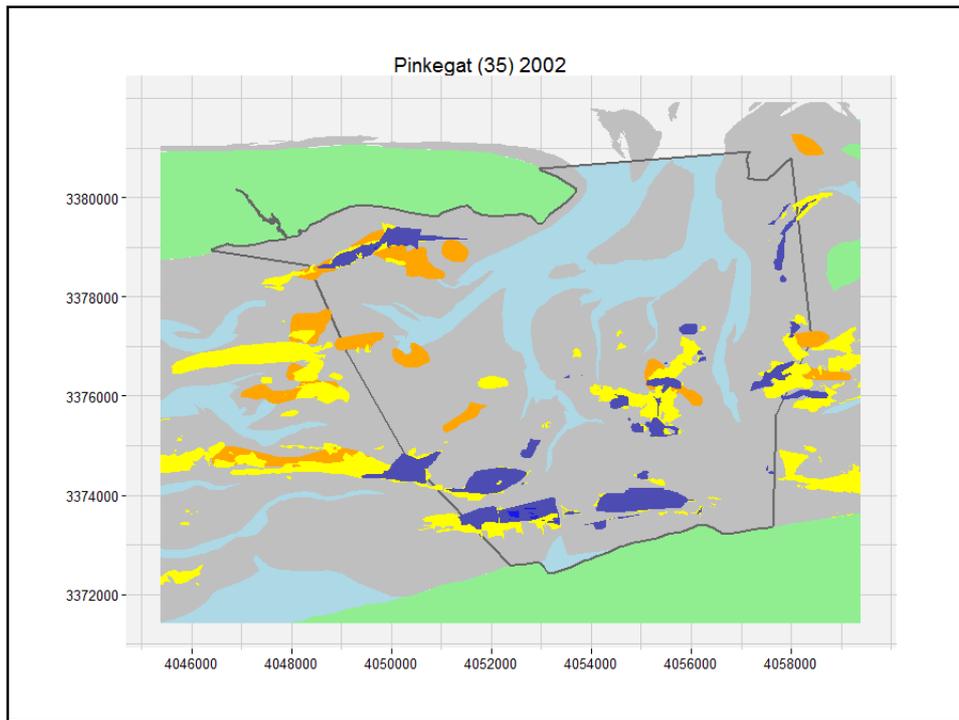
(which include oysters)

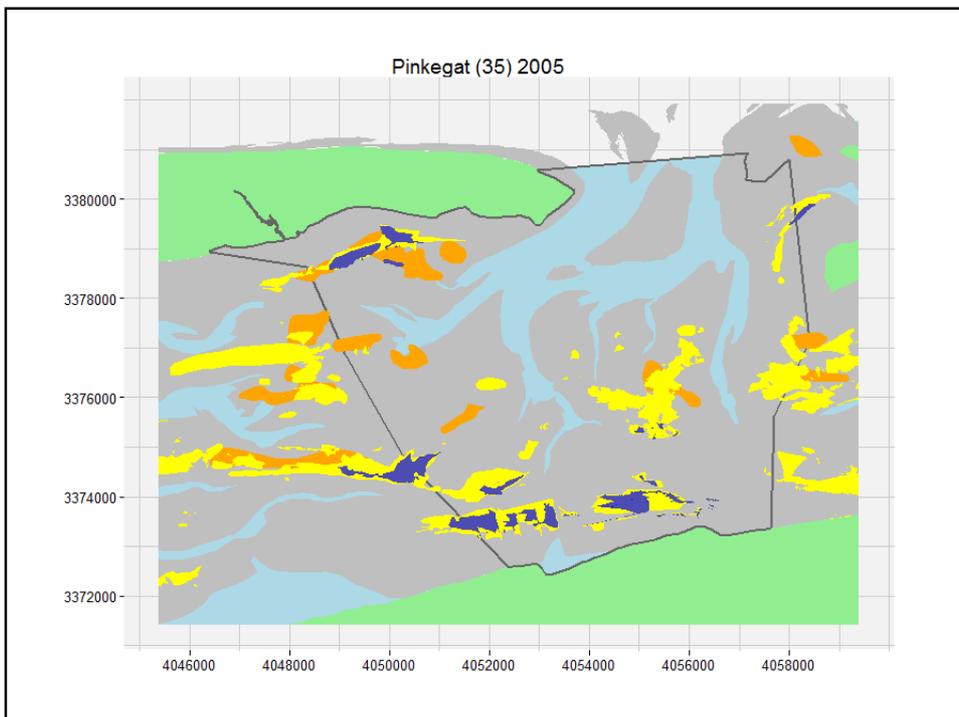
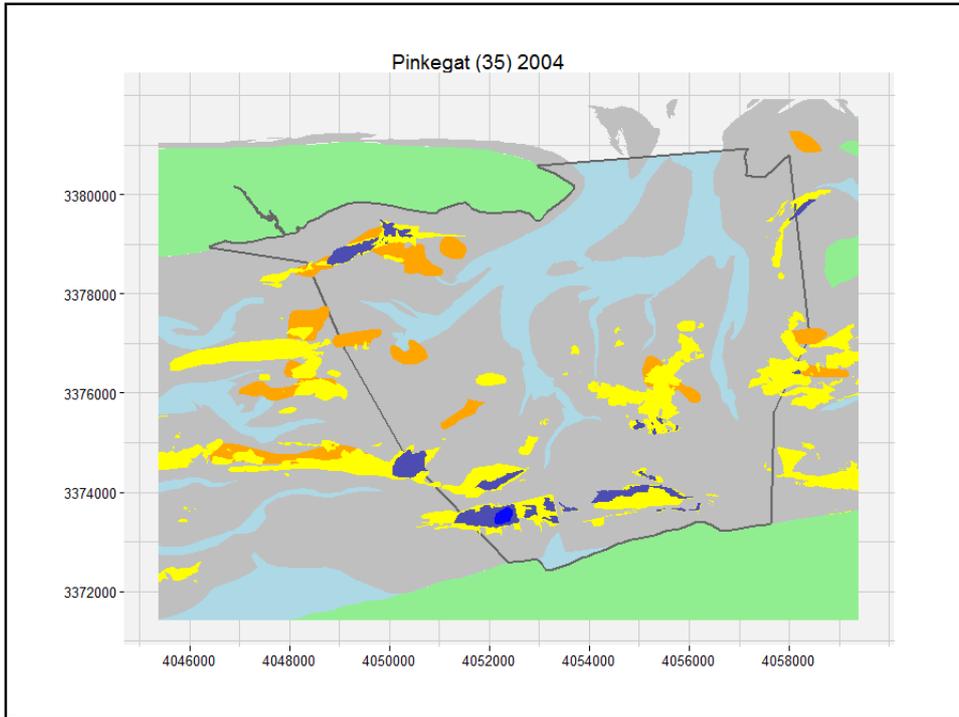


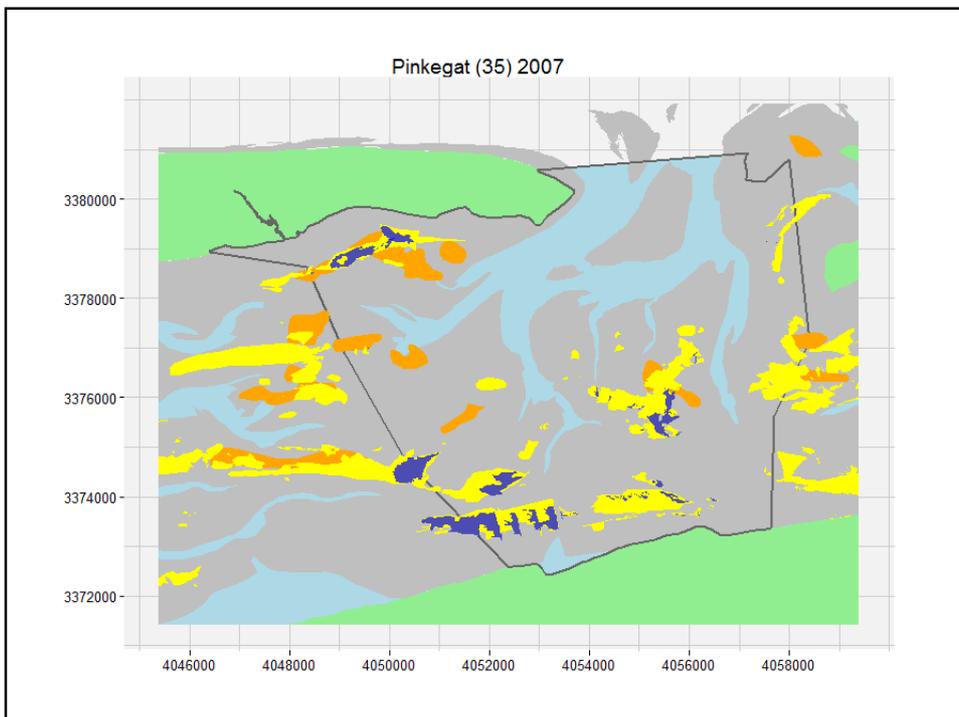
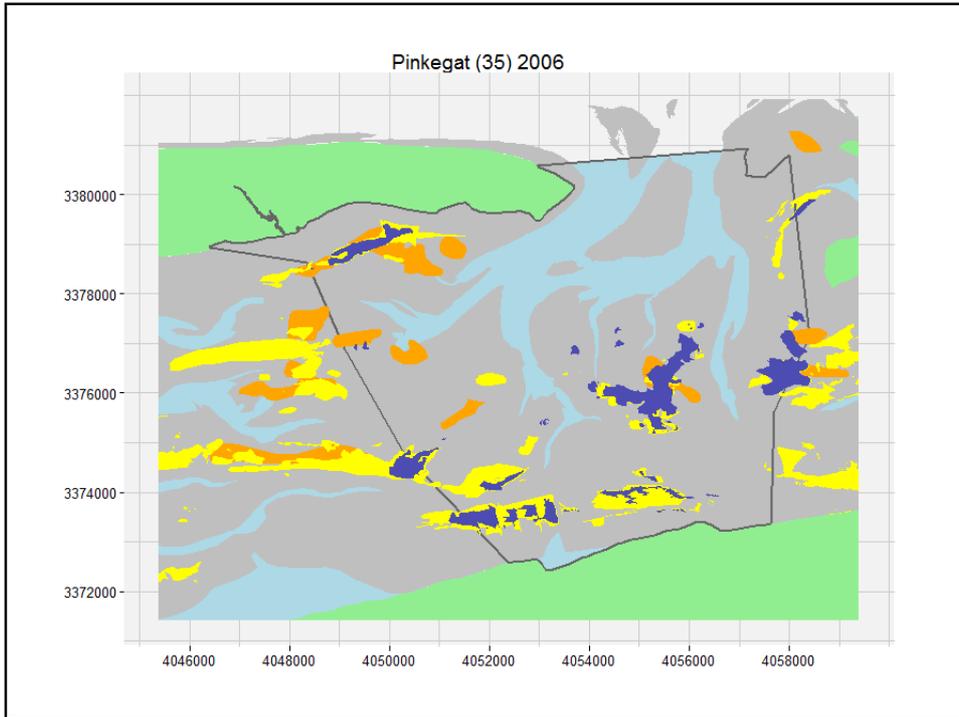
QSR 2004: de Vlas, Brinkman, Buschbaum, Dankers, Herlyn, Kristensen, Millat
 Nehls, Ruth, Steenbergen, Wehrman

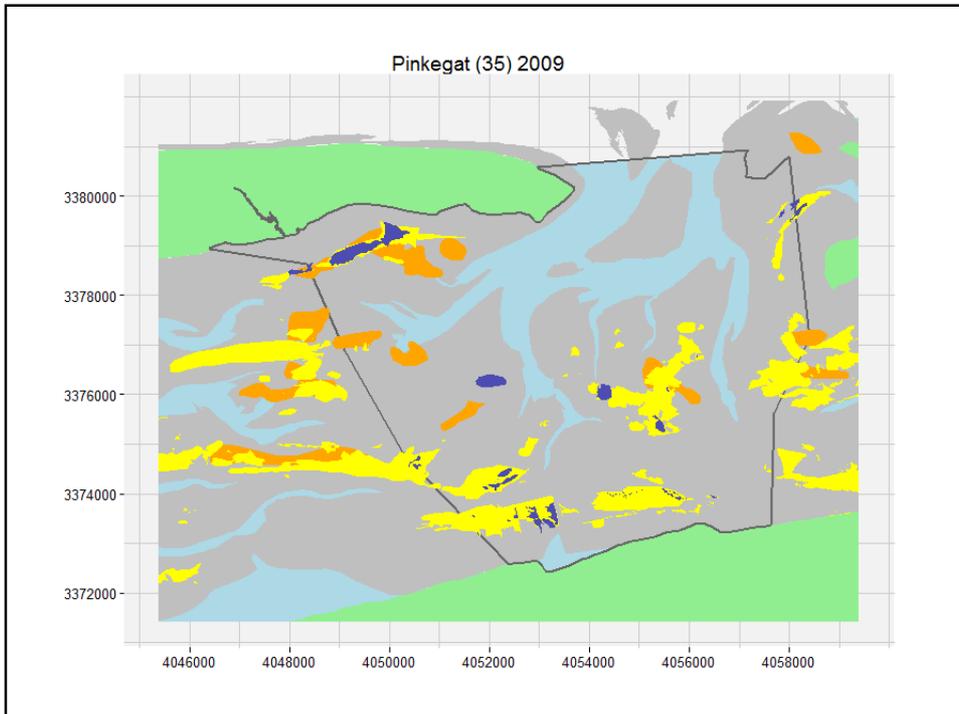
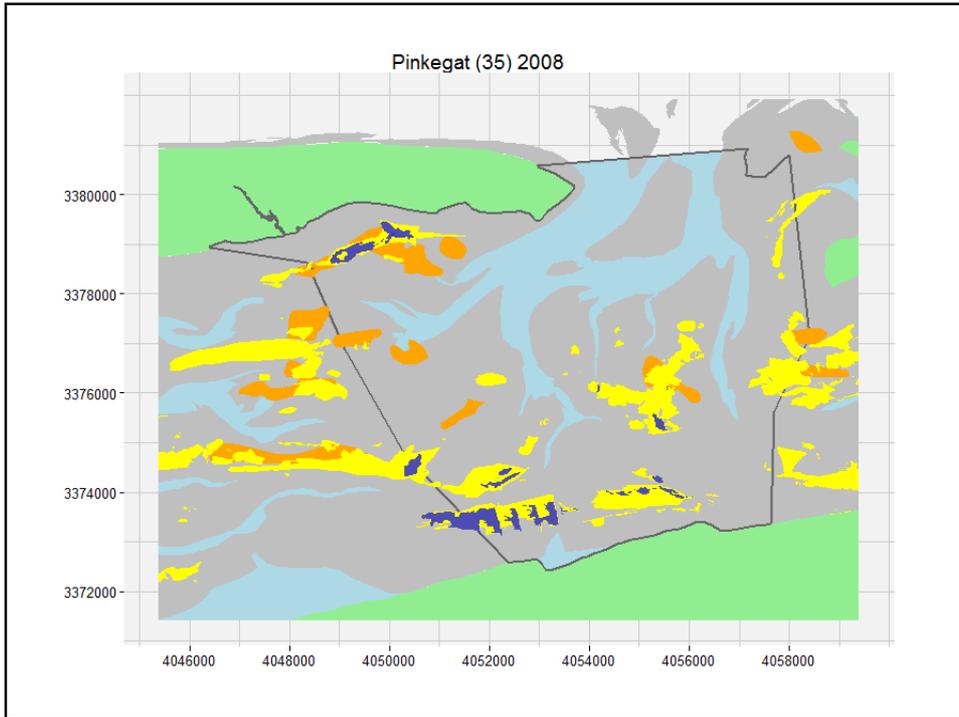
Spatial dynamics and stability

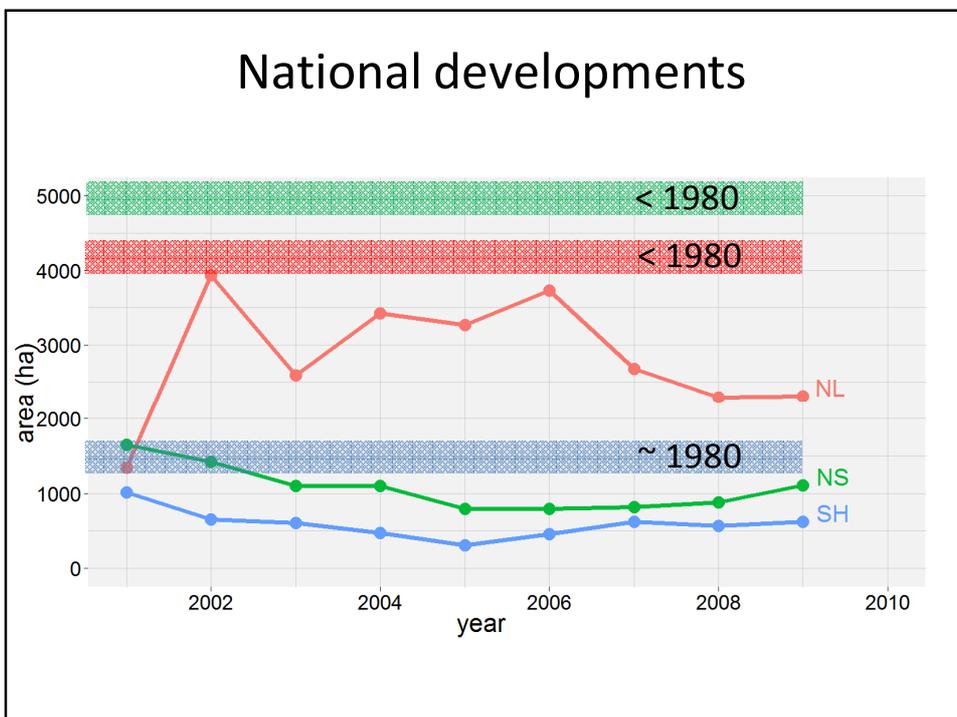
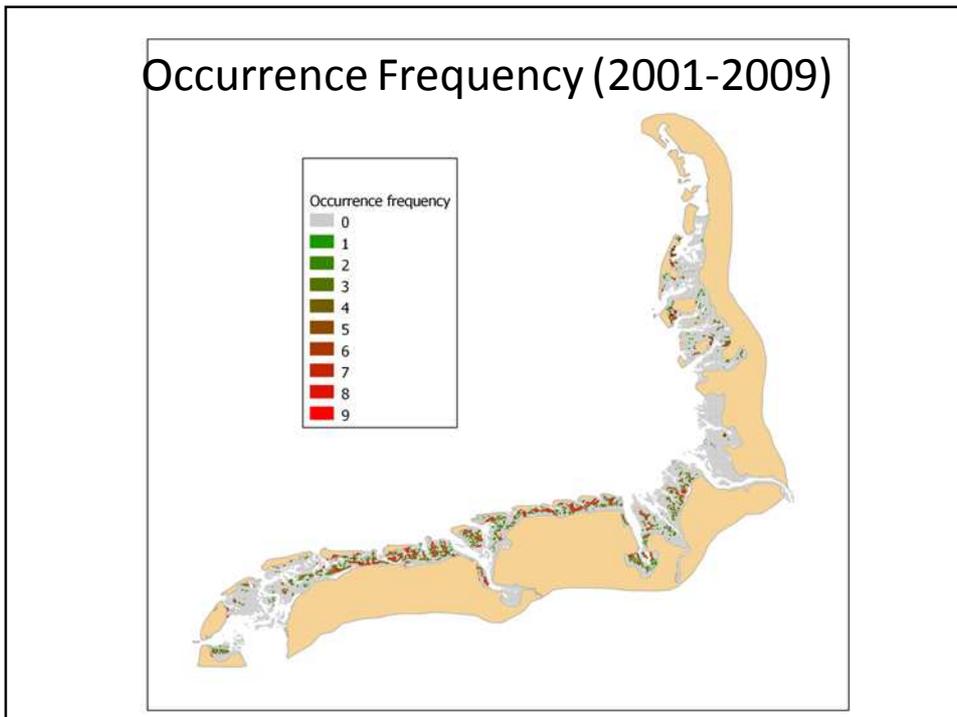


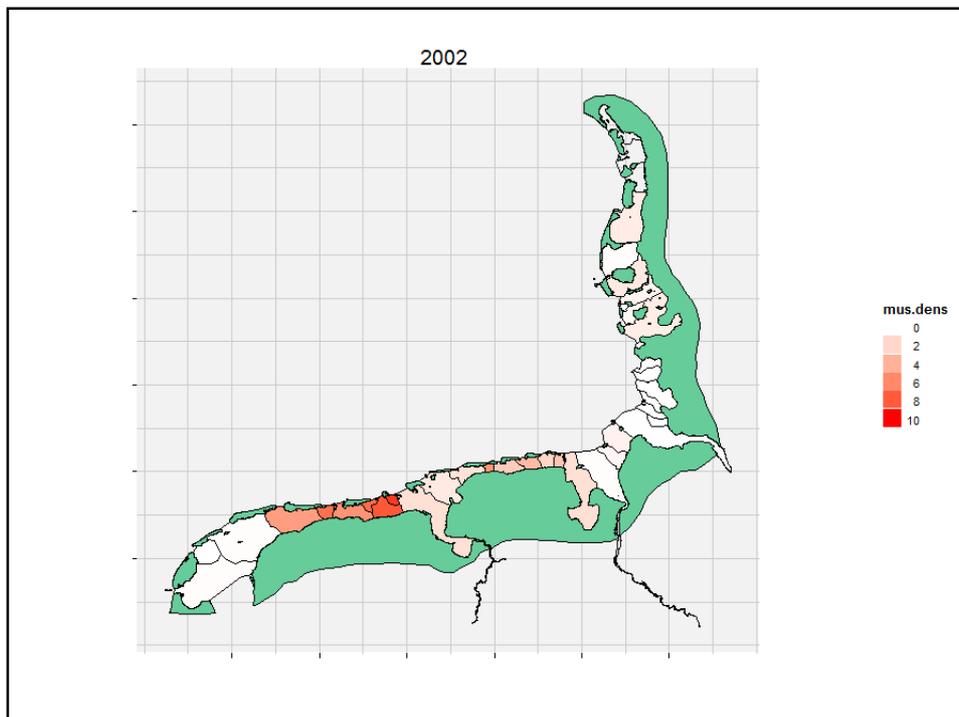
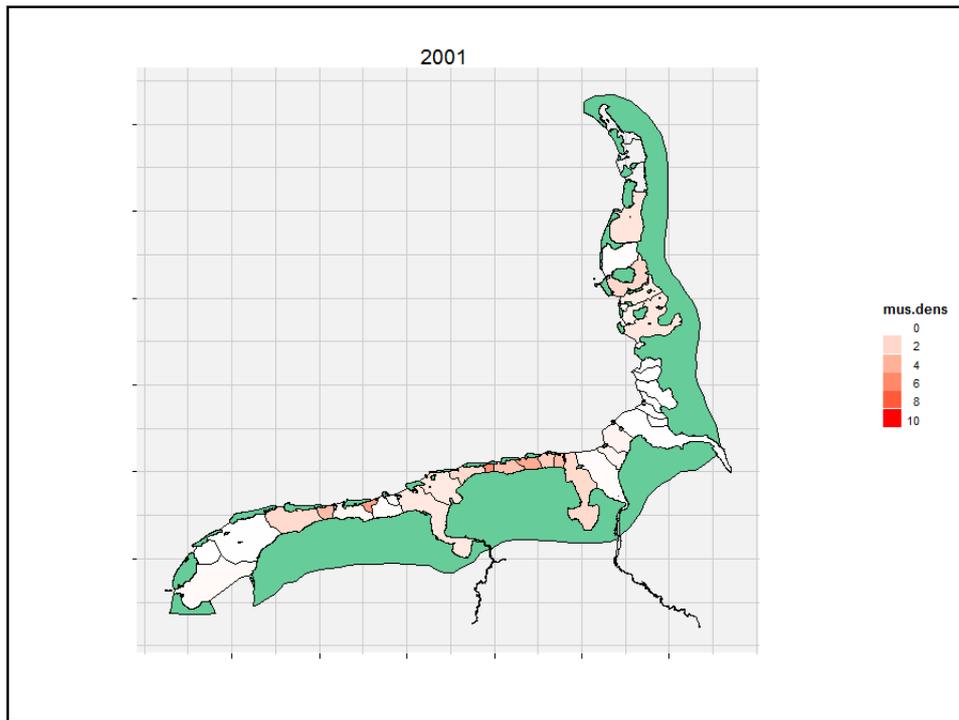


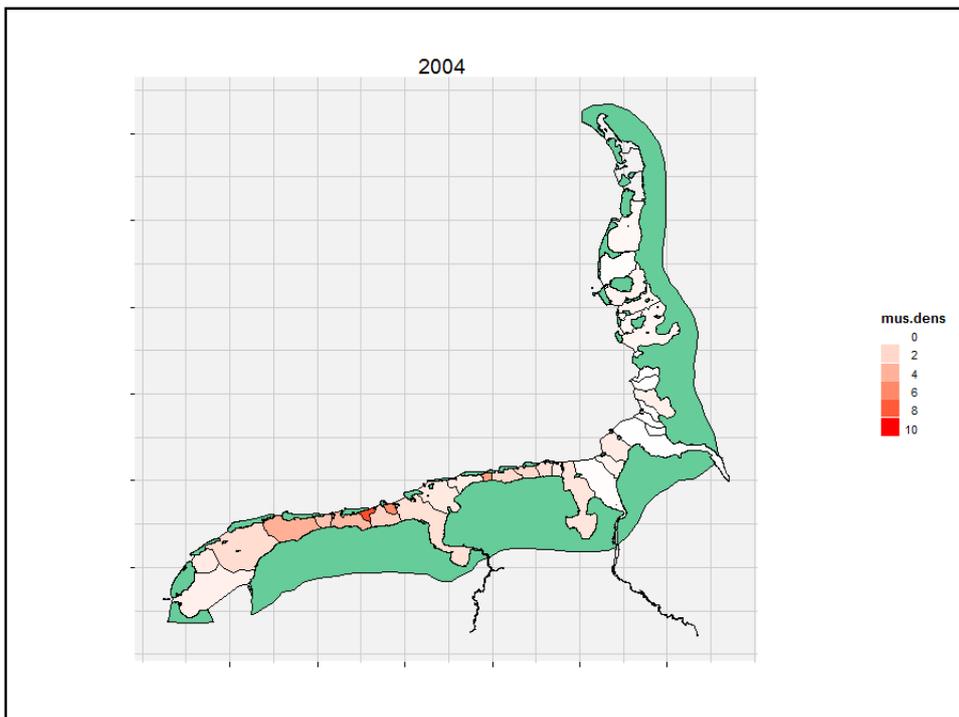
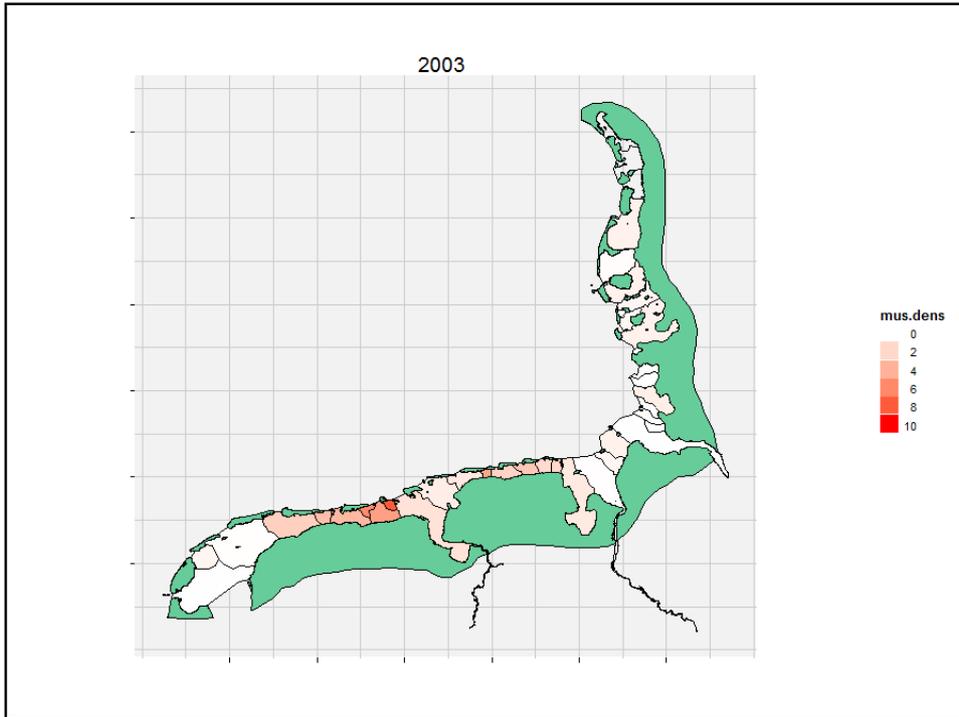


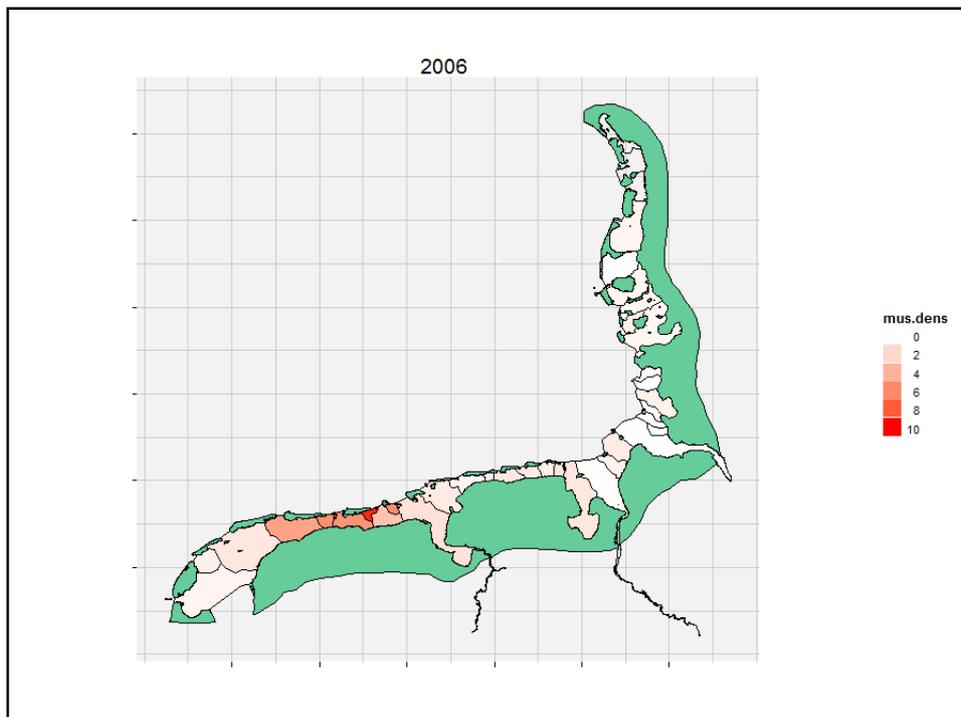
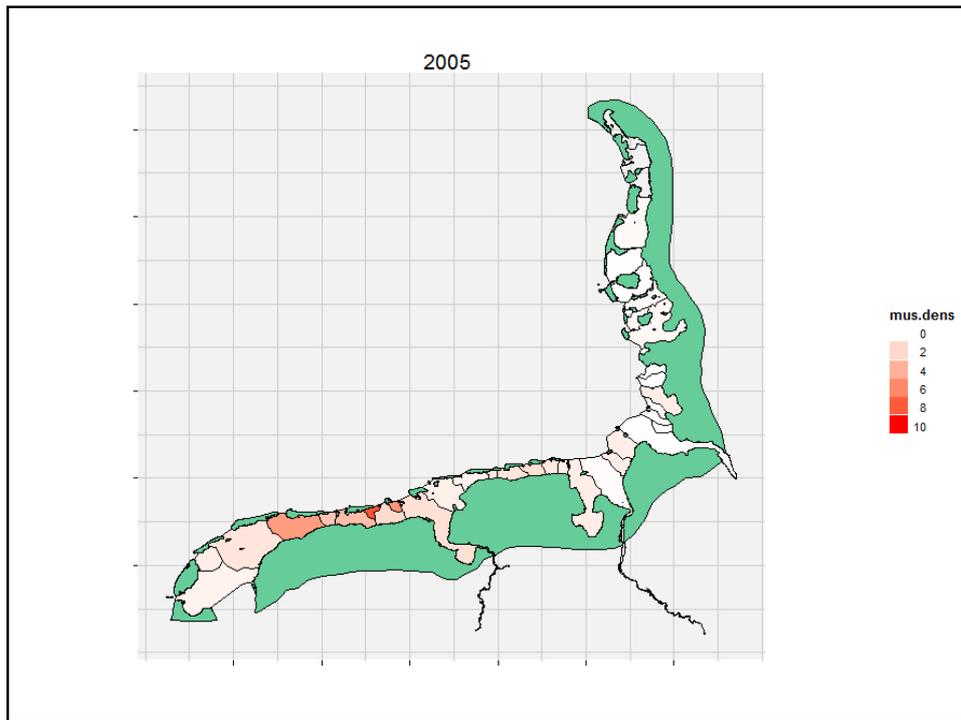


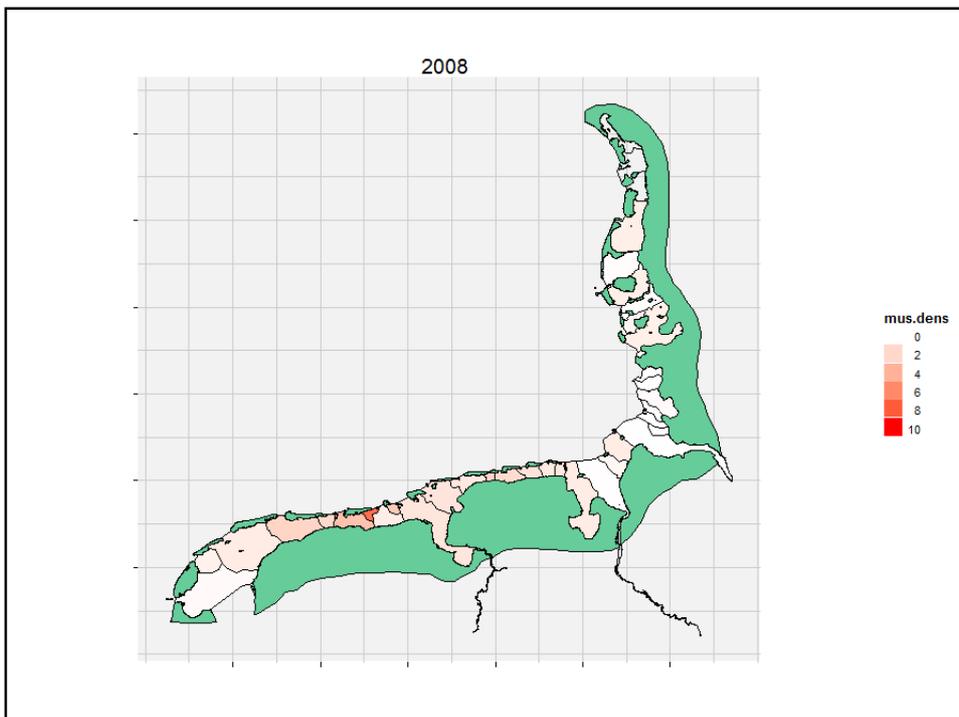
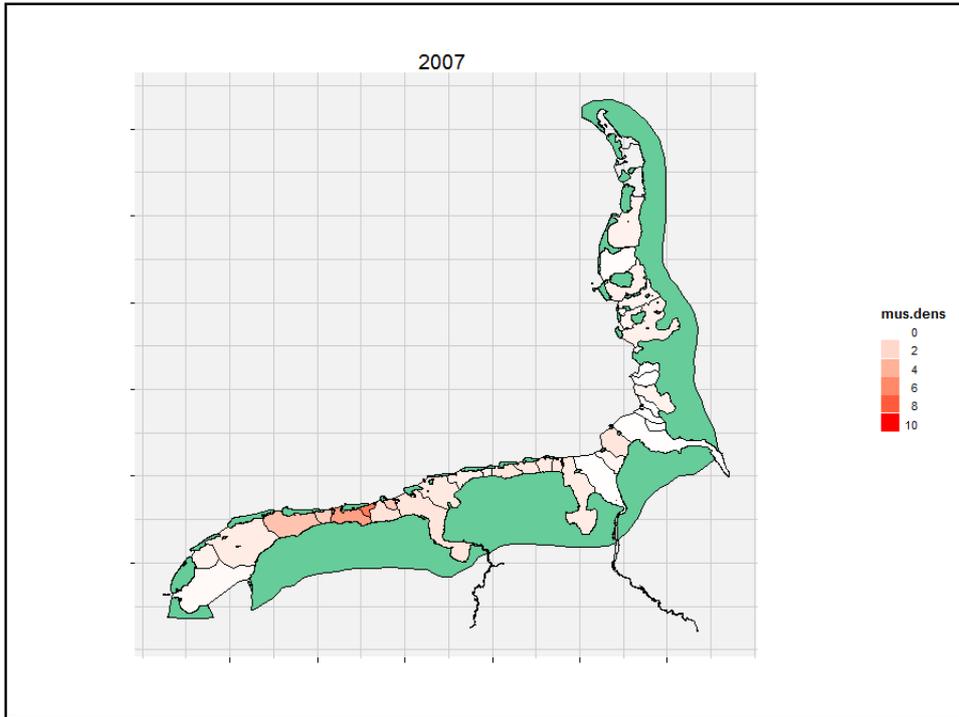


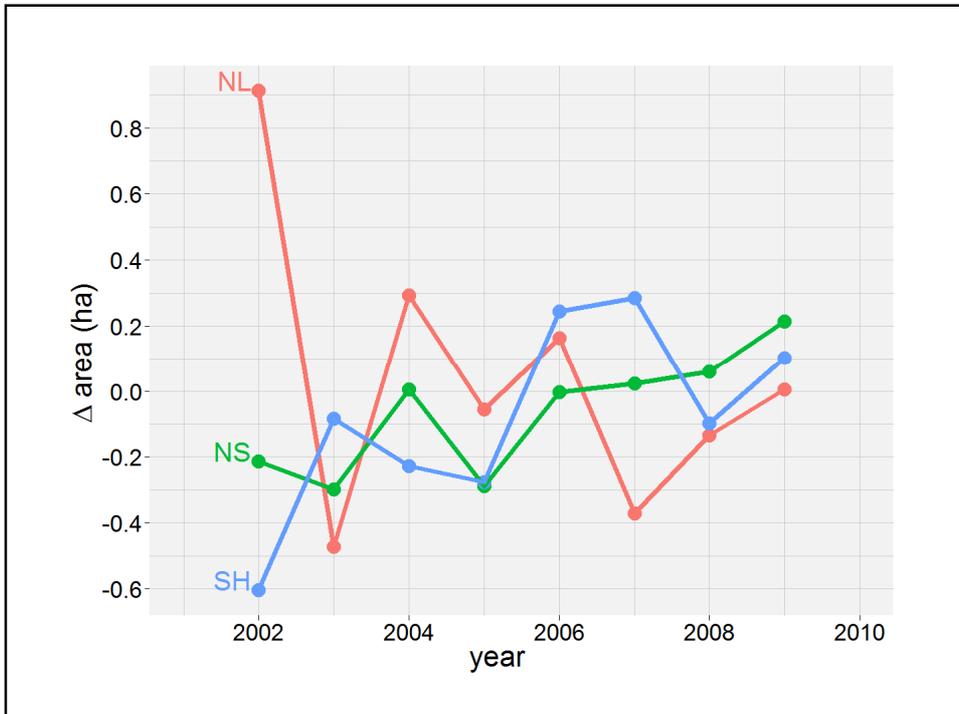
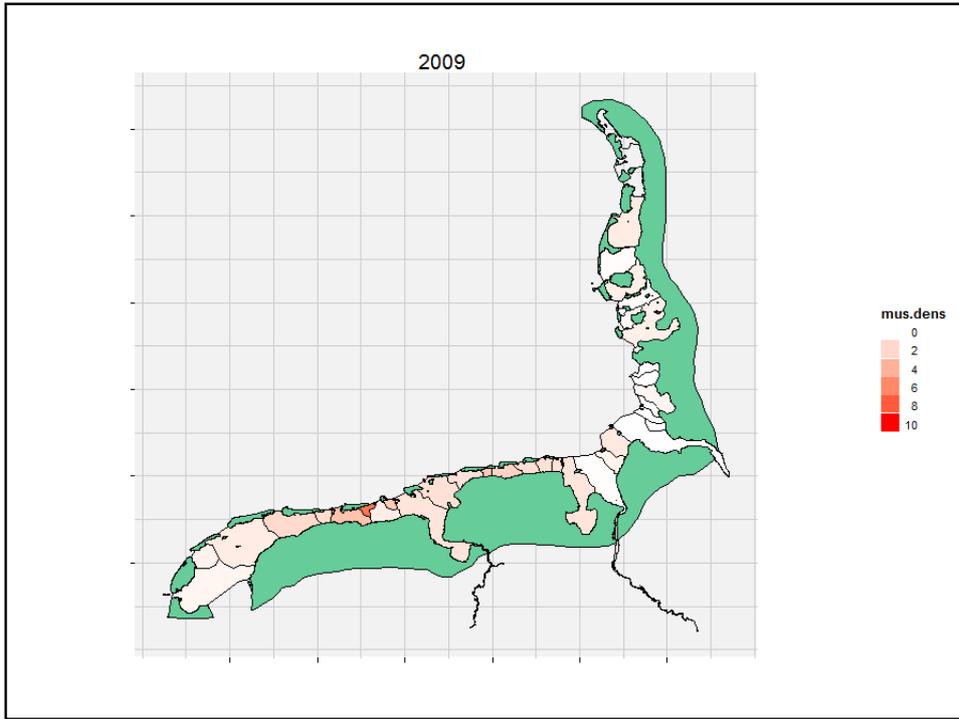




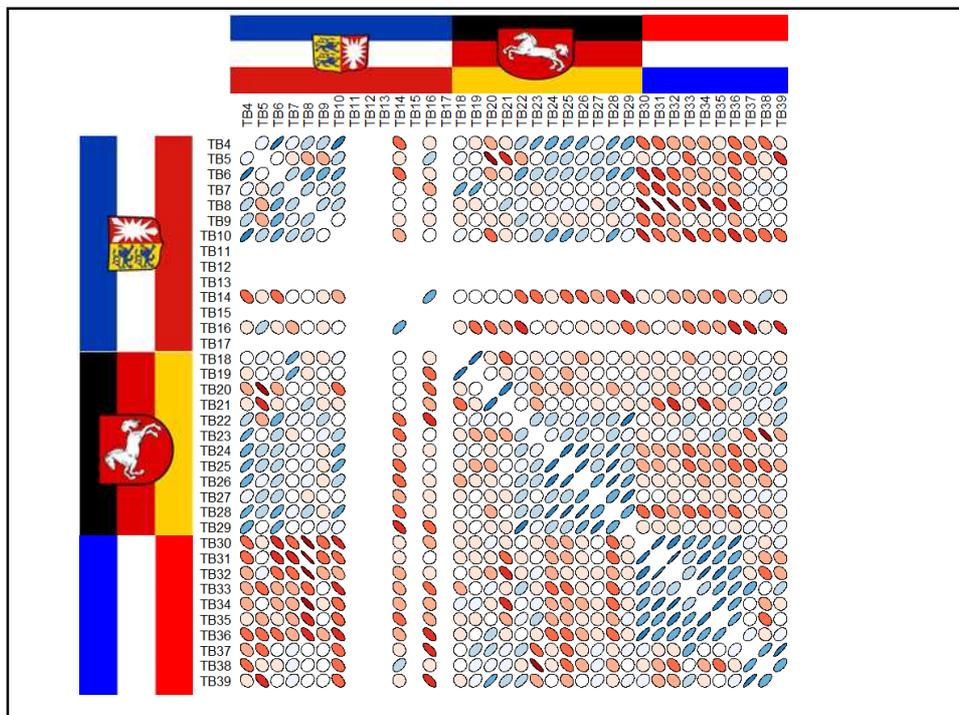
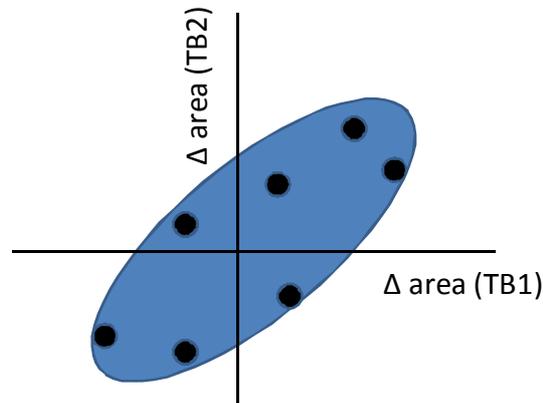


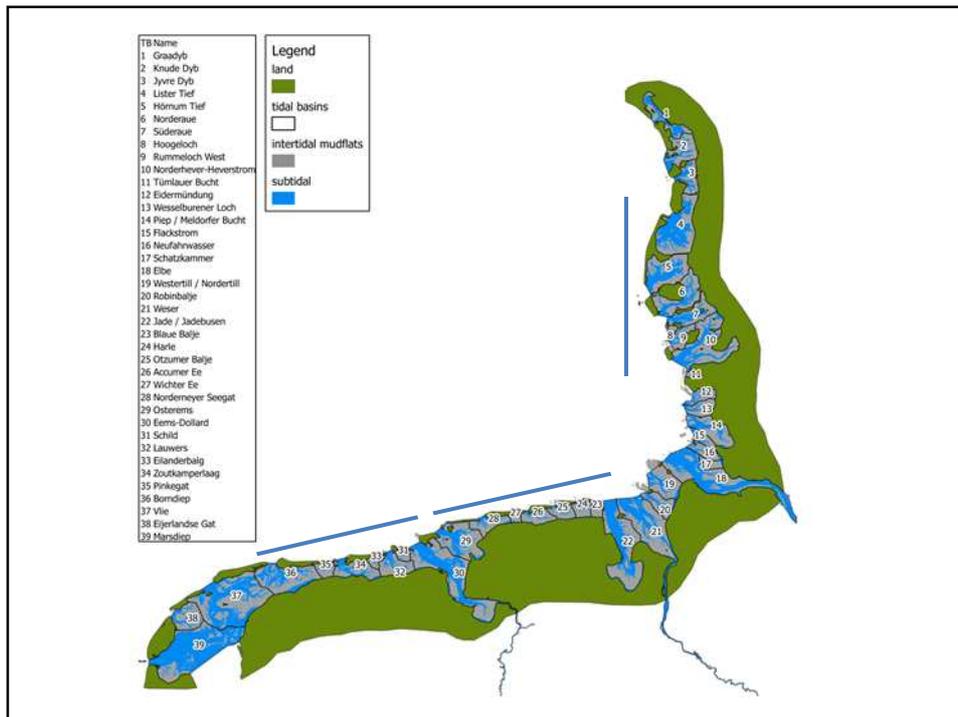






Correlation in change between areas





Conclusions & questions

- It pays to look at “local” dynamics over large scales (i.e. monitoring helps)
- Why do nearby groups of basins synchronize?
 - Temperature (cold winters)?
 - Recruitment
- Should we really be looking on the mudflats?
 - Focus on reproduction instead?
- What else should we know?
 - Food and competition
 - Quality of mussels
 - Recruitment
 - Initial settlement and survival
 - What is the role of brown shrimp?
 - ...

Acknowledgements

- Institutes who provided the data
 - IMARES, NLWKN (NS), BioConsult SH
- R and GIS developers
 - rgeos (Roger Bivand)
 - QGIS & GRASS