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Second Interim Report of the Working Group on the value of Coastal Habitats for Exploited Species (WGVHES)

30 June–4 July 2014

Lisbon, Portugal



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Participants in year 2 of the ICES Working Group on the Value of Coastal Habitats for Exploited Species at the University of Lisbon, Portugal.

From left: Karen van de Wolfshaar, Olivier Le Pape, Rom Lipcius, Håkan Wennhage, Josianne Støttrup, Rochelle Seitz, Rita Vasconcelos, Ken Rose, Dave Eggleston.

Executive summary

This report summarizes the work of the 2014 ICES Working Group on the Value of Coastal Habitats for Exploited Species (WGVHES), held 30 June – 4 July 2014 at the University of Lisbon, Portugal. There were 9 participants from 6 countries (Denmark, France, Portugal, The Netherlands, Sweden and USA); participants included scientific and technical experts with extensive experience dealing with fishery management and conservation issues.

The primary goal of this working group is to provide the foundation for integrating habitat value quantitatively in models of the population dynamics of exploited species, for which ICES gives management advice, as well as those species that are important in the food web of ICES species. The group is attempting to determine the relative value of coastal nursery habitats (e.g. seagrass beds, salt marshes, kelp beds, rocky bottom), feeding grounds, and spawning areas for the suite of species of interest to ICES by (i) documenting and evaluating case studies where the quantity and quality of coastal habitats can be linked directly to the population dynamics of exploited species; (ii) producing reviews that synthesize and critically evaluate the evidence for the importance of coastal habitats to exploited species; and (iii) implementing quantitative methods for determining how coastal habitats influence population abundance and fishery yield. We expect the findings will improve predictions of fishery yield, age-class strength and long-term population status for species of commercial value, and to define habitats for restoration efforts.

This second workgroup meeting consisted of a series of introductory talks by various participants, followed by working sessions of subgroups addressing specific ToRs. The workgroup followed the suggested revision of the ToRs and Work Plan, which are described in section 6. The original ToRs and Work Plan are listed in Sections 2 and 3. At the end of the meeting, a draft interim report was generated.

The accomplishments of the workgroup and subgroups included:

- (i) For revised ToR a (Produce a review paper that synthesizes and critically reviews the evidence for the importance of coastal habitats to exploited species and general patterns that may be applicable over a broad range of situations) two subgroups completed reviews that were published in ICES Journal of Marine Science (JMS). One was entitled “Ecological value of coastal habitats for commercially and ecologically important species” by Rochelle Seitz, Håkan Wennhage, Ulf Bergström, Romuald Lipcius, and Tom Ysebaert, and the other was entitled “Patterns and processes of habitat-specific demographic variability in exploited marine species” by Rita Vasconcelos, David Eggleston, Olivier Le Pape, and Ingrid Tulp. This ToR was therefore completed.
- (ii) For revised ToR b (Produce a review paper on the characteristics and function of natural and anthropogenic hard bottom habitats for fish and invertebrates in coastal waters) a subgroup continued a comprehensive review of natural and anthropogenic hard-bottom habitats of value to exploited species. This review will be completed in 2015.
- (iii) For revised ToR c (Assess availability of coastal habitat maps and distribution for integration into demographic models) the working group concluded that the required habitat types and resolution of habitat maps for integration into demographic models is highly dependent

on the model used, the species under investigation and the research question considered. A general description of available habitat maps were therefore not considered a priority and the ToR will be removed from the work plan.

- (iv) For revised ToR d (Quantify the importance of habitats for exploited species) subgroup activities included (1) completion of a population model for plaice; and (2) completion of a review of quantitative modeling approaches for integrating habitat quality into population models, which will be submitted for publication in 2015.

1 Administrative details

WGVHES – Working Group on the Value of Coastal Habitats for Exploited Species

Year of Appointment – 2013

Reporting year within current cycle (1, 2 or 3) – 2

Chair(s)

Romuald N. Lipcius, USA

Håkan Wennhage, Sweden

Meeting venue

University of Lisbon, Lisbon, Portugal

Meeting dates

30 June–4 July 2014

2 Terms of Reference a) – z)

ToR descriptors

ToR	Description	Background	Science Plan topics addressed	Duration	Expected Deliverables
a	Produce a review paper that synthesizes and critically reviews the evidence for the importance of coastal habitats to exploited species and general patterns that may be applicable over a broad range of situations	In the 2012 workshop three subgroups made a start with three reviews. Two of the reviews were published in 2014, a third will be submitted in 2014, and a fourth review on hard-bottom habitats was added to be submitted for publication in 2015	131,132,134	3 years	Review papers in primary literature
b	Literature studies on quantitative data on fish and invertebrate demographic rates in habitats difficult to census	Focus literature studies on hard bottom habitat types (kelp forests, rocky shores and macroalgae) where many census techniques are inadequate to attain quantitative data	131,132,134	2 years	Review paper in primary literature
c	Quantify coastal habitat availability	Assess the availability of data on different habitat types (habitat quantity), specifically comprehensive habitat maps in cooperation with WGMHM	131,132,134	3 years	Coastal habitat maps for all important habitats
d	Quantify the importance of habitats for exploited species	Attaining quantitative estimates of the importance of habitats for species that are important for the ICES community by modelling	131,132,134	3 years	Paper

3 Summary of Work plan

Year 1	Review papers falling under a and b will be prepared and result in a draft version. In the meeting of 2013 ToR c and d will be started investigating what models will be used and species will be studied
Year 2	Completion of review papers and focus on modelling work
Year 3	Finalise modelling work and identify future research priorities

4 List of Outcomes and Achievements of the WG in this delivery period

Papers

- Vasconcelos R.P., Eggleston D.B., Le Pape O., Tulp I. Patterns and processes of habitat-specific demographic variability in exploited marine species. ICES Journal of Marine Science 71: 638-647.
- Seitz R., Wennhage H., Bergstrom U., Lipcius R., Ysebaert T. Ecological value of coastal habitats for commercially and ecologically important species. ICES Journal of Marine Science 71: 648-665.
- Lipcius R., Eggleston D.B., Fodrie J., Rose, K., Van der Meer J., Van de Wolfshaar K.E., Vasconcelos R. Populations models quantifying the value of coastal habitats for exploited species. In preparation for submission to ICES Journal of Marine Science.

Presentations at ICES ASC 2013

THEME SESSION: Quantitative value of coastal habitats for exploited species

Organizers: Romuald Lipcius (USA), Ingrid Tulp (The Netherlands), Håkan Wennhage (Sweden)

- Rita P. Vasconcelos, Olivier Le Pape, Dave B. Eggleston, Håkan Wennhage, Ingrid Tulp. Quantitative assessment of the value of coastal habitats for exploited marine fish and invertebrates: a review
- Rochelle D. Seitz, Håkan Wennhage, Ulf Bergström, Romuald N. Lipcius, Tom Ysebaert. Coastal habitat use by commercially and ecologically important species
- Romuald N. Lipcius, David B. Eggleston, Joel Fodrie, Julia Moore, Sebastian J. Schreiber, Jaap van der Meer, Karen van de Wolfshaar, Rita Vasconcelos. Population models quantifying the value of coastal habitats for exploited species
- Nicholas Ducharme-Barth, Romuald N. Lipcius, Leah B. Shaw, Junping Shi. Habitat effects on population dynamics and fishery production of the eastern oyster

5 Progress report on ToRs and workplan

ToR a. Produce a review paper that synthesizes and critically reviews the evidence for the importance of coastal habitats to exploited species and general patterns that may be applicable over a broad range of situations

Participants: Rita Vasconcelos, Håkan Wennhage, Josianne Støttrup, Karen van de Wolfshaar, Olivier Le Pape

A new task was proposed under ToR a) as a follow up to the review by Seitz *et al.* 2014 which identified the set of species important to ICES that use coastal habitats for nursery, feeding, spawning or migration. For this new task we aim to identify which life-history typologies are mainly represented among this set of species and report what has been described in the literature for the consequences of habitat loss or degradation at local and population levels. A preliminary structure of the paper follows.

Vasconcelos RP, Wennhage H, Støttrup J, van de Wolfshaar K, Le Pape O. Dependence of exploited species on coastal habitats, importance of life history and habitat use: a review

Introduction

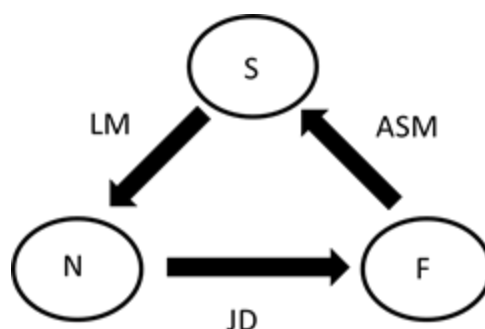


Figure 1. General conceptual diagram of functions and life-stages: N (nursery), F (feeding), S (spawning), LM (larval migration), JD (juvenile dispersal), ASM (adult spawning migration).

Material and Methods

- Review from previous meta-analysis (Seitz *et al.* 2014; 44% of ICES species use coastal habitats).
- Build a typology of functional groups: life history, life stage(s), coastal habitats.
- Separate shellfish (mainly resident and not evaluated by ICES WG) and fishes.
- Select fish species from Table 2 in Seitz *et al.* 2014 (ICES assessed species, 57 fish species out of 59): species that have one existing item of habitat dependence are selected (24 out of 57, 42%).
- Assign species to two life-history types; no pattern with regards to longevity.
- Assign species to two types of habitat use by adults: pelagic or benthic.
- Assign species to different habitat functions in coastal habitats: nursery, feeding, spawning, migration.

- Identifying frequent combinations of habitat use by adults and function, and pooling combinations with few species (<3).
- Focus on the most frequent combinations, and choose one case study for each.
- For these case studies: provide a qualitative categorization (inspired by Petitgas *et al.* 2013) to characterize the importance of habitat dependence on population dynamics and the consequences of habitat quality and degradation on population size and potential of exploitation.

Results

In summary, 6 pelagic fish species (i.e. 55% of the 11 assessed by ICES) and 18 benthic species (38% of the 46 assessed) presented coastal habitat use during at least one stage of their life cycle (Tables 1 and 2).

Table 1. Assignment of each species to: different types of habitat use by adults, and different habitat functions in coastal habitats.

Species	Function in coastal habitat	Pelagic or Benthic adult life stage
basking shark	F	B
sardine	F	P
norway pout	F	B
sea trout	FM	B
eel	FMN	B
cod	FN	B
flounder	FN	B
plaice	FN	B
sole	FN	B
sprat	FN	P
sand eel	FNS	B
herring	FNS	P
salmon	M	B
mackerel	MN	P
sea bass	N	B
dab	N	B
whiting	N	B
striped red mullet	N	B
pollock	N	B
saithe	N	B
anchovy	NS	P
turbot	NS	B
brill	NS	B
capelin	S	P

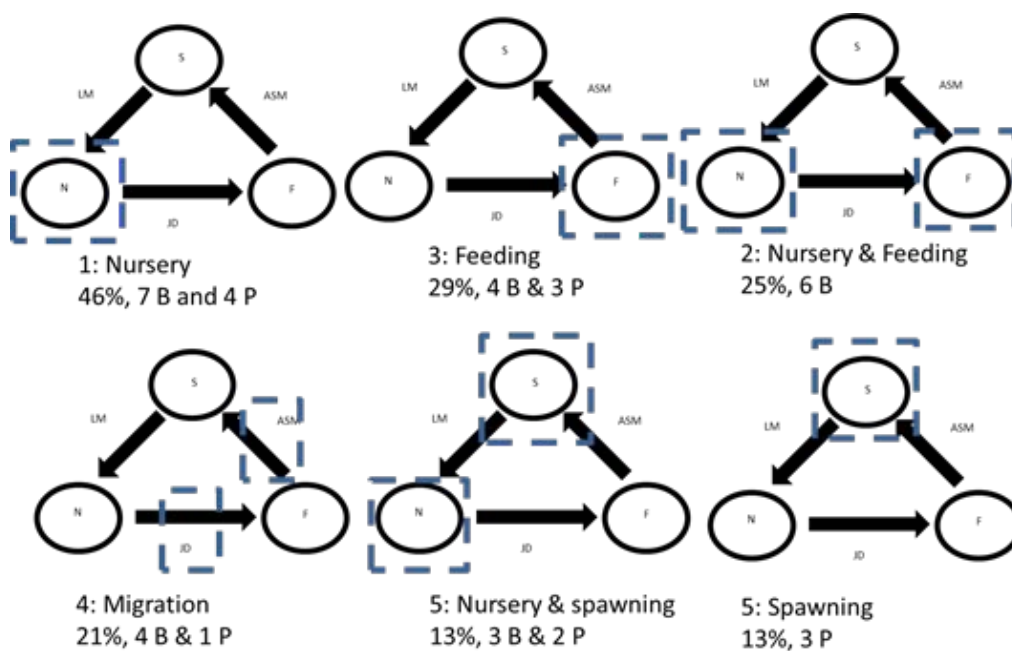
Even if the proportion of pelagic species using coastal habitat is higher than benthic species (55/38% respectively), as most of ICES assessed species are benthic (46/57,

81%) the present typology highlights the functions of coastal benthic habitats for many exploited species. This conclusion could be enhanced as for example herring, a pelagic species, depends on benthic habitats for spawning.

Table 2. Common patterns of habitat use by adults and functions in coastal habitat.

Species group	N	Function	Benthic /Pelagic	Species	Possible case study
Shellfish		Multi-use		oysters, clams, mussels, scallops	Pacific oyster (RV)
Crustaceans		Multi-use		crabs, shrimps, prawns, European lobster	Blue crab / Crangon sp. (KW)
Fish	7	N	B	seabass, dab, whiting, red mullet, pollack, saithe	plaice (KW) cod (HW)
	5	N & F	B	eel, cod, flounder, plaice, sole	
	6	F	B	basking shark, norway pout, sea trout	
	4	N	P	sprat, herring, mackerel, anchovy	sardine/sprat (RV)
	3	F	P	sardine, sprat	
	3	S	P	herring anchovy capelin	Anchovy (OLP)
	3	N & S	B	turbot, brill	Turbot (JS)
	4	M	B	salmon, sea trout	Salmon (OLP)

Figure 2. Diagrams of functions and life stages by habitat use by adults in coastal habitats. The life stage/function that depends on the coastal habitat is highlighted.



Results/Discussion

For each case study we will address the following aspects:

- Biology / life history;

- Habitat types used;
- Degree of habitat loss and degradation in those habitats;
- Links between habitat loss and degradation on population dynamics;
- Take note which population of the species the results refer to.

ToR b. Produce a review paper on the characteristics and function of natural and anthropogenic hard bottom habitats for fish and invertebrates in coastal waters

Participants: Josianne Støttrup, Rochelle Seitz, David Eggleston

Rationale: Hard-bottom habitats are vital to the health and function of coastal ecosystems. These habitats provide nursery areas for juveniles and feeding grounds for adult fish of commercially important fish species. Recent reviews on the importance of coastal habitats for exploited species recognized that there is a lack of information on how fish utilize some habitat types in the North Atlantic, particularly complex hard-bottom habitats such as kelp forests, rocky shores, and macroalgae, where many census techniques are inadequate for quantitative studies (Vasconcelos *et al.* 2014; Seitz *et al.* 2014). Thus, additional information on fish and invertebrate use of these habitats can help promote awareness of the importance of these habitats, and a determination of gaps in knowledge can help direct future research. In Europe, reef habitats are biologically important habitats and are one of the few marine habitat types included in the EU Habitats Directive (1170 Reef Habitat; Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora). For this reason, reef areas are included in national Nature-2000 networks such as the Danish Nature2000 network. In the United States, the Environmental Protection Agency (US EPA) has the Environmental Monitoring and Assessment Program's National Coastal Assessment, which collects estuarine and coastal data from hundreds of stations along the coasts of the continental United States to evaluate the estuarine condition of US estuaries. Types of data include assessment of water quality, benthic communities, demersal fish, and tissue contaminants (<http://www.epa.gov/emap/nca/html/data/index.html>). In addition, each state has different management efforts for protection of hard-bottom habitats (e.g. North Carolina has the Coastal Habitat Protection Plan).

With this working group, we have been conducting a review of temperate hard-bottom habitats and their value for exploited species. Given the lack of information on the characteristics and functions of hard-bottom habitats for fish and invertebrates in coastal waters, we address our review on these habitats. We concentrate on the temperate hard-bottom habitats, which are of particular interest to ICES countries and management. We focus on both natural habitats and artificial reefs. We characterize the use of hard-bottom habitats by both fish and sessile invertebrates. Our objectives are to promote awareness of the importance of these habitats for exploited species and to direct future research.

Approach: Our approach is to use a literature search using the following keywords: hard bottom, rocky reefs, stone reefs, reefs (natural), macroalgae, kelp, riprap (common on US coastlines), wind farms, turbines (common in Danish and Swedish waters), and novel ecosystems. We are reviewing the available literature, and results will be inserted into a table that can be later used in a publication on this subject.

Organization: We will use separate sections for each type of hard-bottom habitat, and the results for each section will include the species supported, structure, function, and demographic rates for organisms supported by the hard-bottom habitat. We will

highlight the importance of habitats in terms of density, growth, survival, and spawning, or in serving the functions of biodiversity, fish and invertebrate production, and anthropogenic use (e.g., recreational fishery, coastal defence). We will write a critical review of monitoring methods used for sampling on hard-bottom habitats. These methods include trawls, baited fishing gear, video monitoring, quadrat sampling, etc. We will conclude with an assessment of the needs and knowledge gaps, including those for appropriate and effective monitoring methods.

The workload for the review during the current and future working group meetings is divided as follows:

Josianne Støttrup will contribute with a critical literature review of results from studies on larger and smaller subtidal stone reefs, focusing on demographic rates, fish production, biodiversity, and other goods and services provided by these reefs relative to their geographical location, hydrographical conditions, and depth. Methane gas reefs, unique to Danish waters, will also be described and any information on these reefs will be reviewed. Information of sampling techniques will be critically reviewed and compared with a view to writing a caveat on sampling limitations relative to this habitat type.

Rochelle Seitz will review the literature on intertidal and subtidal man-made hard-bottom habitats, including riprap and groins, pier pilings, seawalls, and other artificial structures such as bases of offshore energy development structures.

David Eggleston will review literature on the following hard-bottom habitats: (i) artificial reefs such as concrete, metal, rubber, oil platforms, etc., and (ii) natural, hard bottoms such as rocky outcrops (e.g., lithified sediment). Eggleston will populate an excel spreadsheet with literature references with a focus on demographic rates (density, growth, survival, fecundity), and he will produce text that summarizes findings and provide case study examples.

ToR c. Assess availability of coastal habitat maps and distribution for integration into demographic models

Current participant: Håkan Wennhage

The working group concluded that the required habitat types and resolution of habitat maps for integration into demographic models is highly dependent on the model used, the species under investigation and the research question considered. A general description of available habitat maps was therefore not considered a priority and the ToR will be removed from the work plan.

ToR d. Quantify the importance of habitats for exploited species

1. Demographic model for plaice

Current participants: Håkan Wennhage, Josianne Støttrup, Karen van de Wolfshaar

This task has been completed and is being prepared for publication. We recount the summary of the work below.

Both along the Dutch coast and the Kattegat, trawl surveys aimed at monitoring juvenile flatfish abundance show a steep decrease of larger juveniles during the early 1990s, whereas the age 0 group did not show a corresponding dramatic change in density (Table 1). IMARES researchers have hypothesized that the larger juveniles left the shallows for deeper areas due to warming temperatures (Teal *et al.* 2012).

Table 1. Overview of changes of plaice occurrence in the North Sea and Kattegat.

		before	after	Survey	Contact
KA	shallow	0, 1	0	Juvenile Survey Denmark	Josianne Stuttrup
	deep	2+	1+	IBTS	
NZ	shallow	0,1,2	0	DFS	Loes Bolle
	deep	2+	1+	IBTS/DTS	

Given the same phenomenon occurring for two plaice populations a case study on plaice regarding this phenomenon was adopted. To this extent a) comparison was done to investigate in more detail if the observations are indeed comparable and if a mechanism driving the changes can be identified, and b) a model exercise was done to study the effects of large juveniles moving from shallow to deeper habitat on population dynamics.

Data approach: Both the Dutch and the Danish have a juvenile flatfish survey and have the IBTS in waters that serve as plaice habitat. Contact was made with WGBEAM and in particular with the British participants as the UK also has a juvenile and a beam trawl survey. An extension of the areas with plaice nurseries would be of great interest and is being pursued.

Modelling approach: Observations in different regions show that plaice age 1 no longer occur in the coastal areas, and recent publications show that more juveniles are present in deeper waters (Poos *et al.*, 2012; van Keeken *et al.*, 2007; Teal *et al.*, 2012) supporting the suggestion that age 1 plaice moved to deeper waters. The movement from coastal habitat to deeper habitat by age 1 plaice implies that they shifted feeding areas. The consequence is that age 1 plaice no longer compete for food with age 0 plaice, which inhabit the coastal zone, but now compete with older plaice.

To study this effect of larger juveniles shifting habitat and thus shifting competition within the population, a biomass-based stage-structured model (De Roos *et al.*, 2008) was developed. Three stages are recognized and two resources (Figure 2). The small juveniles (S) only forage on the resource in the shallow area (Rs), whereas adults (A) only forage on the resource in the deeper area (Rd). Large juveniles (L) forage on both resources. Thus, the fraction (α) of large juveniles in shallow or deeper areas is varied.

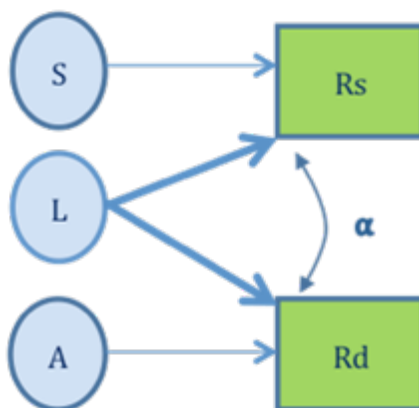


Figure 2. Model schematic. Small juveniles (S) have their resource in the shallow area (Rs), while adults (A) have their resource in the deep area (Rd). Large juveniles (L) change from feeding solely on the resource in the shallows (Rs) to feeding solely on the resource in the deep areas (Rd) by changing α .

In addition, carrying capacity of the two resources may differ. In the North Sea approximately 4% of the area is ≤ 10 m deep (ICES areas 4b and 4c), whereas in the Kattegat, 19% of the area is ≤ 10 m deep.

Parameter values for plaice were taken from Van de Wolfshaar *et al.* (2012). We assumed that the resource recovery rate is equal for shallow and deep areas for simplicity.

Preliminary results: At the meeting a presentation was given on the modelling results. The authors have revised the manuscript, which is being prepared for submission to MEPS.

Manuscript abstract:

Recent studies show that changes in fish species distributions often also include changes in the spatial distributions of particular life-stages. Focus has thus far been on spatial shifts and possible mechanisms, such as climate change. Yet, especially small-scale shifts in habitat of certain life stages may have consequences on population dynamics through changes in resource use and competition, which need to be addressed by (fisheries) management. Based on recently described habitat shifts of North Sea plaice (*Pleuronectes platessa*) a stage-structured model was developed to study the consequences of large juveniles moving from shallow habitat to deep habitat. This shift encompasses a change in resource competition. Large juveniles compete with small juveniles in the shallows and with adults in deeper waters. The results indicate that a short duration shift in habitat of large juveniles to the deeper habitat increases their biomass due to lower resource competition in the deeper habitat compared to the shallow habitat. The biomasses of both adults and small juveniles increase for even higher values of time large juveniles spend in the deeper habitat when resource competition in the shallow habitat is no longer limiting the growth of large juveniles. Increased fishing intensity promotes higher juvenile biomass through overcompensation and differences in habitat productivity may quantitatively affect the population dynamics of plaice. Shifts in habitat may have an effect on the management of species as bycatch may increase. In addition, management of the spatial location of marine protected areas might need reconsideration.

2. Dynamic Energy Budget model for prey of flatfish such as plaice

Current participants: Rochelle Seitz, Jaap van der Meer

The importance of coastal populations of the non-commercially fished Baltic tellin *Macoma balthica*, a small bivalve species as a major food source for the first age classes of several commercially fished flatfish species especially plaice *Pleuronectes platessa*, and also dab *Limanda limanda* and flounder *Platichthys flesus* will be explored. The Wadden Sea has been identified as the most important juvenile habitat for plaice in the North Sea (Rijnsdorp *et al.*, 1984).

We aim to quantitatively assess the importance of this non-commercial prey species for commercial plaice by modelling the energy transferred between the two trophic levels. First, published estimates of overall consumption rates of these flatfish within coastal areas will be compared with published secondary production data of the bivalve species for the relevant size classes. Such a comparison has been made between Baltic tellin and cockle *Cerastoderma edule* production and consumption by birds (Van der Meer *et al.*, 2001), and a modification of this model will be used here.

The modelling will require information on stomach content analyses that indicate what fraction of flatfish consumption consists of the Baltic tellin. Specifically, we will

require data on: (i) Diet composition of plaice for various cohorts (0-group, I-group, II-group); (De Vlas, 1979, 1985; Rijnsdorp and Vingerhoed, 2001); (ii) Intake rates of clams and siphons (Lockwood, 1984; Thijssen, 1974); and (iii) Secondary production (or mortality) of *Macoma* for Wadden sea or north coast (Van der Meer *et al.*, 2001).

De Vlas (1979, 1985) studied in detail the consumption of 0, I and II year age classes of plaice on the Balgzand, a tidal flat area in the western Wadden Sea. He noticed that a major part of the consumption consisted of body parts of the invertebrate fauna, such as bivalve siphons and polychaete tails. *Macoma* siphons were taken April through the beginning of July. The southern portion of the Wadden Sea is where most siphons were taken, as this is where *Macoma* densities are highest (200/m²). Diet of I-group plaice consisted of 20% *Macoma* siphons in April (after which plaice shifted to other prey). De Vlas (1979) noted that "The stomachs of young plaice may contain tens to hundreds of siphon tips." Such body parts can be regenerated and this regrowth may contribute a considerable part of the secondary production of the benthos. Similar findings are reported for the North Sea, where for example arms of the brittle star *Amphiura filiformis* are an important food source for fish (Duineveld & Van Noort, 1986). In addition, diet composition of plaice has been similarly identified to include ~20% bivalves (Rijnsdorp and Vingerhoed, 2001) after about 13 cm fish size.

A Dynamic Energy Budget (DEB) model will be developed, which will incorporate regrowth of body parts. Such a model is an extension of the standard DEB model, which has already been applied to *Macoma balthica* (Van der Veer *et al.*, 2006). In the DEB model used for *Macoma* effects on birds (Van der Meer *et al.*, 2001), for each summer and winter between 1973 and 1998 estimates of the secondary production of *Macoma balthica* and *Cerastoderma edule* were obtained by the removal summation method. The production for those age-classes that were profitable as a food source for two shellfish eating birds, the oystercatcher *Haematopus ostralegus* and the knot *Calidris canutus*, were compared with the consumption by the bird populations. This consumption was estimated by multiplying the counted numbers of birds present with a literature based energy demand per individual bird. Results showed a weak relationship between annual production and consumption, pointing to unknown sources of mortality in high-production years (Figure 4).

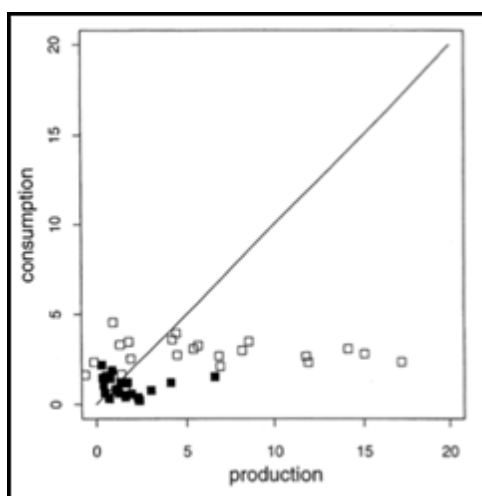


Figure 4. Winter consumption (g AFDM m⁻²) as a function of winter production (g AFDM m⁻²) of prey of suitable size for knots (filled squares) and oystercatchers (open squares). Each point refers to a winter from the period 1975/1976 to 1997/1998.

Progress: Jaap van der Meer was unable to attend this workgroup meeting, so this task has been postponed until the next workgroup meeting.

3. Dynamic Energy Budget (DEB) model and population model for oyster species including *Ostrea* and *Crassostrea* spp.

Current participants: Jaap van der Meer, Romuald Lipcius, David Eggleston, Rochelle Seitz

Three of the main biotic and environmental drivers expected to affect habitat suitability of fish and invertebrates in coastal habitats are water temperature, food availability, and dissolved oxygen levels. Water temperature has been increasing, dissolved oxygen levels have been depleted, and food availability has varied significantly, and these are expected to influence metabolic demands, growth and reproduction of fish and invertebrates. As examples of these effects we will model the influence of temperature, food availability and dissolved oxygen on two species of oysters, the European flat oyster *Ostrea edulis* and the eastern oyster *Crassostrea virginica*, using DEB models as described above. In addition, we will use an existing DEB model of the Pacific oyster *Crassostrea gigas*, an exotic species introduced to Europe, to assess the likelihood that these two species will co-occur in Europe's coastal habitats in the future. We will also adapt an existing demographic model for the eastern oyster to assess the role of harvest-induced degradation on oyster reef habitats and populations.

Progress: Jaap van der Meer was unable to attend this workgroup meeting, so this task has been postponed until the next workgroup meeting.

4. Review of quantitative modelling approaches for integrating habitat quality into population models

Current participants: Romuald Lipcius, Jaap van der Meer, Karen van de Wolfshaar, Joel Fodrie, David Eggleston, Rita Vasconcelos, Ken Rose

Many exploited marine and estuarine populations have experienced significant reductions in spawning stock biomass and recruitment. For instance, in an assessment of global FAO marine fisheries data for 210 stocks, 27% were fully exploited, 25% were overexploited, and 16% had collapsed. Concurrently, essential habitats such as nursery and foraging grounds have been degraded in many areas such that these critical habitats are no longer adequate to fulfil nursery, feeding or reproductive functions (Airoldi and Beck, 2007). Although the influence of coastal habitats on specific rates of survival, growth, and reproduction of exploited marine species has been demonstrated widely (Beck *et al.*, 2001; Heck *et al.*, 2003; Minello *et al.*, 2003), the absolute value of these habitats to their population dynamics has rarely been quantified. Consequently, it has been difficult to estimate the optimal extent of habitat required for the persistence and sustainable use of exploited species, and therefore, to effectively manage habitat with respect to abundance of exploited species. In addition, recent research indicates that many species inhabit linked sets of primary (e.g. seagrass beds) and secondary (e.g. salt marsh fringed coves and shorelines) nurseries (e.g. Lipcius *et al.*, 2007). Yet there is little to no information on the relative value of these different nurseries to the population dynamics of exploited species, leading to the recognition that effective fishery management will require modelling the effects of habitat upon population dynamics. Thus, we sought to lay the foundation for determining the quantitative value of coastal nursery habitats, feeding grounds, and spawning areas for exploited species by defining suitable population modelling approaches that assess variation in population abundance and fishery yield as a function of habitat. In the 2012 Workshop on the Value of Coastal Habitats for Exploited

Species (WKVHES), we began a comprehensive review of the different modelling approaches (statistical and mathematical) that would be useful for modelling the quantitative effects of habitat upon fisheries production and population dynamics. During the 2013 and 2014 Working Group meetings of WGVHES, we continued the review and added habitat suitability modelling as a complementary tool for integrating habitat into population models. In the review we also describe the methods involved in each of the modelling approaches and provide examples of their implementation and utility to facilitate their use in ecosystem-based fishery management. We expect that such population models will improve predictions of fishery yield and long-term population status for species of commercial and recreational value, and reveal key habitats for restoration efforts. The review is being prepared as a manuscript for submission to MEPS.

5. Potential integration of individual-based models into population models

Kenneth Rose (LSU) presented two examples of how individual-based modelling has been used to relate changes in physical habitat to fish and shellfish recruitment and productivity. The first example was a model that simulated multiple species on an hourly time step as they moved onto and off artificial reefs in the Gulf of Mexico (Campbell *et al.* 2011). Many oil and gas structures have been left in the water as part of a popular “rigs-to-reef” program, whereby structures become state-maintained and offer recreational fishing opportunities. The modelling addressed the question of at what point does an area get saturated with artificial reefs such that fish productivity no longer increases sufficiently to justify the costs of maintaining the reefs. They simulated the hourly movement of individuals for 50 years on a 2-dimensional (90 x 90) grid of 200 x 200 meter cells, with specific cells designed as artificial reef cells. There was little food but high protection from predators when individuals were located on reef cells. Other cells had 5 types of commonly eaten prey represented as separate logistic growth functions of biomass. During the night, individuals moved off the reef cells to forage on the bottom cells surrounding the reef cell. At dawn, individuals moved to the nearest reef cell for protection during daytime. Mortality increased with distance from the reef and with the number of predators in the same cell. The more individuals on a reef and the closeness of reefs to each other caused depressions in the prey biomass surrounding the reef cells, and thus individuals had to forage in cells farther away from the reef cells to maintain their growth rates. Results were used to determine the density of reefs in an area and inter-reef distances that caused significant interference via competition for prey and resulted in diminishing increases in productivity.

The second example also used an individual-based model to show how the spatial arrangement of vegetated cells within a marsh-water system affects young shrimp productivity during the spring through fall (Roth *et al.* 2008). Shrimp in coastal Louisiana enter the coastal marsh system in April, grow rapidly, and return to open coastal and ocean waters in the fall as they reach about 70 mm and become vulnerable to the fisheries. The model simulated individual shrimp from multiple weekly cohorts entering the system on a 2-dimensional map (500 by 500) of 1 m x 1 m cells, with cells designated as open water or vegetated. Hourly growth was faster and mortality rate lower when shrimp were on vegetated cells. Each cell was assigned an elevation, and hourly water levels determined water depth in each cell and therefore which were accessible by the shrimp. Five-month simulations (April through August) were performed for vegetated/open cell maps obtained from aerial photographs that represented a progression of healthy to decaying marshes. Several measures of productivity were analysed, including the number surviving to 70 mm, biomass in-

crease due to growth of individuals, and the biomass removed due to mortality that was assumed to feed predators. All measures of productivity showed a dependence on the amount of vegetated cells (habitat quantity) and, in some cases, on the spatial arrangement of the vegetated cells within a map.

Both examples demonstrated how individual-based modelling can be used to provide a mechanistic basis for quantifying habitat effects on fish and shellfish. The keys are having sufficient data and information to configure and test such models, and how to scale the results of such models, which must operate on relatively fine spatial and temporal scales, to the population level.

Campbell, M.D., K.A. Rose, K. Boswell, and J. Cowan. 2011. Individual-based modelling of an artificial reef fish community: Effects of habitat quantity and degree of refuge. *Ecological Modelling* 222: 3895–3909.

Roth, B.M., K.A. Rose, L.P. Rozas, and T.J. Minello. 2008. Relative influence of habitat fragmentation and inundation on brown shrimp *Farfantepenaeus aztecus* production in northern Gulf of Mexico salt marshes. *Marine Ecology Progress Series* 359: 185–202.

6 Next meeting

Date and Venue for the meeting in year 3:

29 June–3 July 2015, Palermo, Sicily, Italy.

Annex 1: List of participants

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Annex 2: References

- Airolidi, L, and M W Beck. 2007. Loss, status and trends for coastal marine habitats of Europe. *Oceanography and Marine Biology: An Annual Review* 45: 345–405.
- Beck, K L Jr, G Hays, and R J Orth. 2003. Critical evaluation of the nursery role hypothesis for seagrass meadows. *Marine Ecology Progress Series* 253: 123–136.
- Beck, M W, K L Heck Jr, K W Able, D L Childers, D B Eggleston, B M Gillanders, B Halpern, C G Hays, K Hoshino, T J Minello, R J Orth, P F Sheridan, M P Weinstein. 2001. The identification, conservation, and management of estuarine and marine nurseries for fish and invertebrates. *BioScience* 51: 633–641.
- de Roos, A M, T Schellekens, T van Kooten, K E van de Wolfshaar, D Claessen, and L Persson. 2008. Simplifying a physiologically structured population model to a stage-structured biomass model. *Theoretical Population Biology* 73: 47–62.
- De Vlas, J. 1979. Annual food intake by plaice and flounder in a tidal flat area in the Dutch Wadden Sea, with special reference to consumption of regenerating parts of macrobenthic prey. *Netherlands Journal of Sea Research* 13(1): 117–153.
- De Vlas, J. 1985. Secondary production by siphon regeneration in a tidal flat population of *Macoma balthica*. *Netherlands Journal of Sea Research* 19(2): 147–164.
- Duineveld, G C A, and G J Van Noort. 1986. Observations on the population dynamics of *Amphiura filiformis* (Ophiuroidea: Echinodermata) in the southern North Sea and its exploitation by the dab, *Limanda limanda*. *Netherlands Journal of Sea Research* 20(1): 85–94.
- Heck, K L Jr, G Hays, and R J Orth. 2003. Critical evaluation of the nursery role hypothesis for seagrass meadows. *Marine Ecology Progress Series* 253: 123–136.
- Lipcius, R N, D B Eggleston, K L Heck Jr, R D Seitz, and J van Montfrans. 2007. Post-settlement abundance, survival, and growth of postlarvae and young juvenile blue crabs in nursery habitats. In *Biology and Management of the Blue Crab*, eds. V S Kennedy and L E Cronin. University of Maryland Press.
- Lockwood, S J. 1984. The daily food intake of 0-group plaice (*Pleuronectes platessa* L.) under natural conditions: changes with size and season. *Journal Conseil international for Exploration du Mer* 41: 181–193.
- Minello, T J, K W Able, M P Weinstein, and C G Hays. 2003. Salt marshes as nurseries for nekton: testing hypotheses on density, growth and survival through meta-analysis. *Marine Ecology Progress Series* 246: 39–59.
- Poos, J J, G Aarts, S Vandemaele, W Willems, L J Bolle, and A T M van Helmond. 2013. Estimating spatial and temporal variability of juvenile North Sea plaice from opportunistic data. *Journal of Sea Research* 75: 118–128.
- Rijnsdorp, A D, and B Vingerhoed. 2001. Feeding of plaice *Pleuronectes platessa* L. and sole *Solea solea* (L.) in relation to the effects of bottom trawling. *Journal of Sea Research* 45(3): 219–229.
- Rijnsdorp, A D, M Van Stralen, and H W Van der Veer. 1985. Selective tidal transport of North Sea plaice larvae *Pleuronectes platessa* in coastal nursery areas. *Transactions of the American Fisheries Society* 114(4): 461–470.
- Seitz, R D, H Wennhage, U Bergstrom, R Lipcius, and T Ysebaert. Value of coastal habitats for exploited species: Coastal habitat use by commercially and ecologically important species. *In Review*. ICES Journal of Marine Science.
- Teal, L R, R van Hal, T van Kooten, P Ruurdij, and A D Rijnsdorp. 2012. Bio-energetics underpin the spatial response of North Sea plaice (*Pleuronectes platessa*) and sole (*Solea solea*) to climate change. *Global Change Biology* 18: 3291–3305.

- Thijssen, R, A J Lever, and J Lever. 1974. Food composition and feeding periodicity of O-group plaice (*Pleuronectes platessa*) in the tidal area of a sandy beach. *Netherlands Journal of Sea Research* 8(4): 369-377.
- van de Wolfshaar, K E, T Schellekens, J J Poos, and T van Kooten. Interspecific resource competition effects on fisheries revenue. *Plos One* 7(12): e53352.
- van der Meer, J, T Piersma, and J J Beukema. 2001. Population dynamics of benthic species on tidal flats: the possible roles of shorebird predation. Pp. 317-355 In: *Ecological Studies*, Vol. 15: *Ecological Comparisons of Sedimentary Shores*. (Ed) K Reise. Springer-Verlag, Berlin.
- Van der Veer, H W, J F Cardoso, and J van der Meer. 2006. The estimation of DEB parameters for various Northeast Atlantic bivalve species. *Journal of Sea Research* 56(2): 107-124.
- Van Keeken, O A, M van Hoppe, R E Grift, and A D Rijnsdorp. 2007. Changes in the spatial distribution of north Sea plaice (*Pleuronectes platessa*) and implications for fisheries management. *Journal of Sea Research* 57: 187-197.
- Vasconcelos R, D B Eggleston, O Le Pape, and I Tulp. Patterns and processes of habitat-specific demographic variability in exploited marine species. Submitted to *ICES Journal of Marine Science*.