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Abstract

For many years, the planning and management of terrestrial areas has been supported by a detailed knowledge of the distribution of habitats and their associated species. However, the detailed mapping of biological resources in extent coastal areas, such as the Norwegian coastal zone, is unrealistic due to its enormous coastline. Here, we present a useful and feasible approach and a set of simple, cost-effective methods which are suitable for providing a broad-scale overview of marine habitats and fish resources. This approach was developed in conjunction with a pioneer study conducted along the southern coast of the Skagerrak, where we combined knowledge gathered from local fishermen with scientific knowledge of important species and nature types to establish a coastal sea mapping program. GIS modeling tools were used in both the mapping program and to integrate local and scientific knowledge into digital maps made available to local area management. This multi-faceted approach, which combines local knowledge and scientific methods, provides valuable information with respect to marine biodiversity, and has been used extensively by local environmental management.

Keywords (separated by '-') Coastal zone management - Fish resources - Habitat mapping - Stakeholders - Norwegian Skagerrak coast

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REVIEW PAPER

Mapping Biological Resources in the Coastal Zone: An Evaluation of Methods in a Pioneering Study from Norway

Jan Atle Knutsen, Halvor Knutsen, Eli Rinde, Hartvig Christie, Torjan Bodvin, Einar Dahl

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Abstract For many years, the planning and management of terrestrial areas has been supported by a detailed knowledge of the distribution of habitats and their associated species. However, the detailed mapping of biological resources in extent coastal areas, such as the Norwegian coastal zone, is unrealistic due to its enormous coastline. Here, we present a useful and feasible approach and a set of simple, cost-effective methods which are suitable for providing a broad-scale overview of marine habitats and fish resources. This approach was developed in conjunction with a pioneer study conducted along the southern coast of the Skagerrak, where we combined knowledge gathered from local fishermen with scientific knowledge of important species and nature types to establish a coastal sea mapping program. GIS modeling tools were used in both the mapping program and to integrate local and scientific knowledge into digital maps made available to local area management. This multi-faceted approach, which combines local knowledge and scientific methods, provides valuable information with respect to marine biodiversity, and has been used extensively by local environmental management.

Keywords Coastal zone management · Fish resources · Habitat mapping · Stakeholders · Norwegian Skagerrak coast

INTRODUCTION

Biological resources in the coastal zone are under extensive pressure worldwide. Over the past 20 years, there has been a fundamental change in our understanding of the human impact to the coastal marine environment. Previously, the public focus has primarily been on pollution, although today, habitat destruction, climate change, invasive species, and overfishing must also be taken into account to maintain a high biodiversity in coastal seas.

Over the past few decades, the high demand for coastal resources has led to extensive use of the coastal zone, and resulted in irreversible damage and loss of important biological resources in coastal areas throughout Europe. Commercial fisheries have ceased to operate due to pollution in many coastal areas (Bakke et al. 2006; Næss et al. 2002; Dahl et al. 2008), the anthropogenic impact has degraded coastal marine habitats and ecosystems (Phil et al. 2006; Baden et al. 2003), and invasive species have re-organized the biodiversity of the shallow coastal waters (Carlton 1996). Overharvesting has contributed to a well documented collapse in some coastal fish populations (e.g., Atlantic cod; Svedäng and Bardon 2003; Myers et al. 1996).

For years, terrestrial areas have been managed based upon a detailed knowledge and comprehensive data on the distribution of habitats and their associated species (Wundram and Loeffler 2008). Much of this information is visualized on maps easily available to local, regional, and national management. By contrast, only maps showing bathymetric features and on rare occasions, physical, and chemical oceanographic data, exist for undersea areas. Until recently, little focus has been addressed with regard to the identification and mapping of marine biological resources in the coastal zone, with a particular scarcity of such information in temperate areas. Recent studies have either been concentrated on a single habitat type, e.g., Stål and Pihl (2008) performing a quantitative investigation for the utilization of shallow areas for fishing along a specific part of the western Swedish coast, or on one particular resource or habitat, e.g., Stål et al. (2007) studying the distribution and quality of plaice nursery grounds.

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The coastal zone of the Skagerrak is the most populated part of the Norwegian coast. During the last few decades, there has been an expanded use of the coastal zone in Norwegian waters, and development has been carried out with no consideration of the biological assets, with irreversible consequences for biological diversity (Dahl et al. 2008; Knutsen et al. 2003). It is important to establish a management procedure for the coastal zone that will ensure a continuation of the remaining biological diversity and productivity. Obviously, a detailed knowledge of marine habitats and biological resources, and marine species and their ecological relationships is needed. Even so, such mapping is highly demanding and at present not possible to accomplish for extent coastal areas, such as the Norwegian coastal zone. The aim of this article is to present a useful and feasible approach together with a set of simple, cost-effective methods suitable for providing a broad-scale overview of marine habitats and fish resources. The approach and methods were developed in a pioneering study on the Norwegian Skagerrak coast. We combined local and scientific knowledge to establish a relevant and cost-effective sea mapping program, and discussed how the acquired information may be used by local environmental management.

MATERIALS AND METHODS

Study Area

This pioneering study was carried out in the Tvedestrandfjord on the Skagerrak coast of Norway in 2002. The fjord system is 8 km long, and the water circulation is reduced due to several sills among three well-defined water basins (Fig. 1). Hydrographical and chemical studies have been conducted along the Skagerrak coast since 1928 (Johannessen and Dahl 1996). Studies of the water masses of the Tvedestrandfjord have revealed severe a deoxygenating of the water below sill levels in the basins (Knutsen et al. 2003; Johannessen and Dahl 1996; Dahl et al. 1987). Kroglund et al. (1998) studied the seaweed vegetation at different localities in the fjord and found that opportunistic green and brown algae, which tolerate high levels of nutrients, dominated the shoreline.

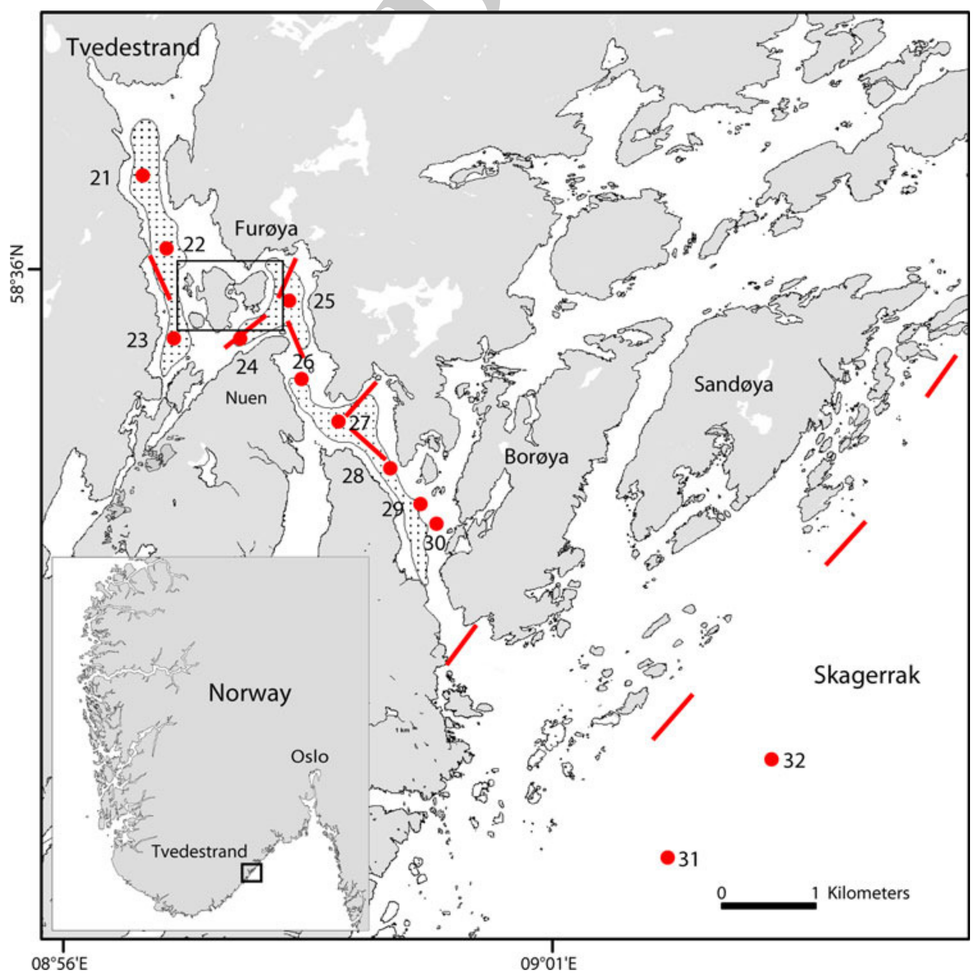

Fig. 1 Study area showing: egg stations (*filled circle*) from the Tvedestrandsfjord to off coast, gill net locations (*solid line*), and spawning areas for cod (*circled times*) where three different criteria were fulfilled: **a** more than two local fishermen marked an area as an important spawning ground independent of each other, **b** spawning cod were captured, and **c** cod eggs were identified

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Available GIS Layers

The Norwegian Mapping Authority provided digital bathymetric maps of the marine areas of Tvedestrandfjord, with a resolution of 25×25 m^2. In order to identify areas with an appropriate slope, we established a slope layer from the bathymetric model as well as used a wave exposure model (Isæus 2004), which was later applied for the entire Norwegian coast in the national mapping and monitoring program on biological diversity (Longva 2006). These maps were used for interviews, for planning transects with scuba diving and video recording, and for the GIS-analyses.

Selected Benthic Habitats and Fish Resources

A national guide describing key habitats and fish resources in the coastal zone, published by the Directorate of Nature Management (DN) in 2001, constituted the basis for selecting which habitats/resources to map. The list was expanded to include nursery areas for fish and seagrass beds (later included in the revised version of the DNs list; DN 2007). The following benthic habitats were mapped: seagrass beds (*Zostera marina* and *Ruppia maritima*), soft bottom areas (mud flats), and *Laminaria hyperborea* kelp forests. Registered occurrences of the various habitats were labeled on maps according to the proposal from the DN (2001) and the Norwegian mapping standard known as SOSI. SOSI is the Norwegian standard for the exchange of geographical data, and includes codes for different subject areas, such as biodiversity and fishery science. The system is closely related to international standards developed by ISO/TC211. The aim with respect to biodiversity is to describe biological data registered through different mapping projects under management, to create a standard for the sampling and documentation of species and nature type distribution, as well as area use. The code list for marine nature types at present is shown in Table 1.

Interviews

Mapping of spawning, nursery areas, and marine habitats were based on interviews of 12 local fishermen with a thorough knowledge of local areas within the study area. The interviews were performed independently and conducted according to pre-made forms. Information was recorded by the individual fishermen on available maps directly (e.g., locations of different nature types, fishing areas, spawning areas, and other relevant information).

GIS Modeling of the Distribution of Seagrass Beds, Mud Flats, and Kelp Forests

Based on the bathymetric and wave exposure maps, transects were selected and mapped in the field to assess the upper and lower values for the distribution of seagrass beds, mud flats (soft bottom areas), and kelp forests along the depth and wave exposure gradients using the methods described above. Based on these values and on some general criteria for

Table 1 Code list of marine nature types in SOSI from the website of the Norwegian mapping authority, 14 September 2009, draft of English version of SOSI standard version 4 for biodiversity (http://www.statkart.no/sosi/)

Nr	Code name	Definition/Description	Code
13	Code list/BdNatureTypeMarine	Prioritized nature types collected through municipal surveys of important biodiversity areas in accordance with DN Manual 19-2001, surveying marine biodiversity.	
13.1	Large kelp forest areas		I01
13.2	Strong tidal currents		I02
13.3	Fjords with low oxygen content		I03
13.4	Deep fjords		I04
13.5	Round fjord with narrow inlet		I05
13.6	Litoral basins		I06
13.7	Ice-marginal deposits		I07
13.8	Soft bottom areas in the beach zone		I08
13.9	Corals		I09
13.10	Loosely bedded calcareous algae deposits		I10
13.11	Eelgrass community		I11
13.12	Shell sand		I12
13.13	Oyster populations		I13
13.14	Major scallop populations		I14
13.15	Other important populations		I15

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Table 2 Criteria used in the GIS analysis for the different habitat types

Depth (m)	Corrected depth	Slope (angle)	Corrected slope	Exposure	Habitat
0–2		<10°	<3°	Partly exposed to protected	Soft bottom areas-mudflats
1–7		<25°	<7°	Slightly exposed to protected	Seagrass beds
3–15	3–15 in mod exp 3–20 in exposed	>25°	Independent of slope	Exposed	Kelp forest (*Laminaria hyperborea* communities

occurrences across the gradient's slope and wave exposure based on the long-term field experience of scientists (Table 1), a GIS overlay analysis was applied to identify the probable distribution of these benthic habitats.

Methods to Identify and Verify Marine Habitats

The following three methods were used to identify marine habitats in the field:

(a) In late autumn during nights with calm weather and clear seas (excellent visibility), a small boat with strong lights was used to survey shallow areas (<10 m depth) to verify the existence of seagrass beds suggested by GIS analysis and interviews. Seagrass beds and mud flats are easily recognized by this method. In addition, hydroscopes were used during the daytime to identify bottom substrates and vegetation types.

(b) Scuba diving was used in the summer to identify the distribution of marine habitats to a depth of approximately 20 m. For kelp a forest, 5–10 transects were designed to evenly span potential distribution areas identified by local fishermen and GIS analysis. For seagrass beds, scuba diving was used to verify the distribution and lower depth limits of exposed, moderately exposed and sheltered areas at 10 locations of the different exposure classes.

(c) In summer, an underwater video camera (Dacon Sub Sea) was launched from the Research Vessel (RV) "G. M. Dannevig". The camera focused vertically on the bottom and was connected by cable to a monitor on board the ship. In combination with a GPS-based OLEX system (http://www.olex.no/index_e.html), benthic habitats (including kelp forests, sand, or rock-dominated substrates, and "degree of hardness of the substrate") were plotted directly onto digital maps. This method was especially useful in areas not suitable for scuba diving due to strong currents (e.g., in shallow offshore areas). The study area was visited twice and the criteria for the distribution of kelp forests and seagrass beds were improved during the last visit (cf. Table 2).

Field Verification of Spawning and Nursery Areas for Fish

In order to verify the information obtained through interviews concerning spawning areas, we performed: (a) egg sampling and (b) test fishing with traditional fish nets during the spawning period from February to April. It was decided to specifically focus on fish species of commercial interest (cod and pollack). Areas were only assigned as active spawning areas if all the following criteria were fulfilled: (a) the spawning grounds were identified independently by more than two fishermen during the interviews, (b) fish eggs were included in the samples, and (c) spawning fish were captured in the same area. Analogously, nursery areas for fish species of commercial interest were assigned as active if identified independently by more than two fishermen. Nursery areas operate through a combination of several factors, such as density, growth, survival of juveniles, and movement to adult habitats, and are crucial for the survival of newly settled larvae (Beck et al. 2001).

Egg Sampling

Vertical tows with a plankton net (WP2-diameter: 60 cm, mesh width: 500 µm, filtering approximately 8.4 m^3 of water each haul) were performed from the RV "G. M. Dannevig" in a transect from the inner section of the fjord to the exposed areas outside the fjord mouth. This design covers areas identified as both spawning areas by local fishermen and areas not identified as spawning areas (i.e., control areas). The hauls were performed during three temporal occasions (weeks 8, 11, and 14) to ensure hitting the spawning period for cod. We tested for the difference in the average number of eggs between these areas in week 14 (locations 21–30 vs. locations 31 and 32 in Fig. 1) using a *t*-test. The boat was kept in roughly the same position during the tow by the use of GPS and a nearby reference landmark, and the tows were taken from a depth of 30 m. The net was raised at a speed of 0.5 m s^{-1} (Barnes 1949) to avoid turbulence in the opening, and the eggs were

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counted and identified according to standing literature (Hiemstra 1962; Hoek and Ehrenbaum 1911; Russel 1976).

Test Fishing

Based on the designated spawning areas obtained from the interviews, test fishing was executed by use of a standardized series of 30 fishnets (24.0 × 5.5 m, 80 mm bar mesh) within the spawning period for cod and pollack (February–April). On each sampling occasion, the nets were set at the precise locations marked by the fishermen, and we fished for about 18 h. The fish were frozen and later weighed (*W* in g), measured (total length L_T in mm), sexed, and classified as either juvenile, maturing (about to spawn within the season of capture), or spawned. Fish age was estimated from otholiths (Fotland et al. 2008).

Distribution of Maps to Local Management

The resulting maps for the likely distribution of the studied habitats (kelp forests, seagrass beds, mud flats, and spawning and nursery areas for fish), based on combining the results from the interviews and field sampling, were digitalized and transformed to the standard SOSI–map system. The resulting digital maps (SOSI-files) were included in the official map system of Tvedestrand municipality, and made available to the public through a web-based solution (www.tvedestrand.kommune.no).

RESULTS

The Tvedestrandsfjord contains a unique variety of biological assets in the coastal zone. Consequently, a diversity of marine habitats and a number of spawning and nursery areas for fish were identified during the study.

Seagrass Beds

Both sets of criteria for this habitat overestimated the distribution of seagrass beds in the Tvedestrandfjord. During the second field survey, we observed that the slope limit seemed to decrease with exposure, from roughly 10° or higher at the sheltered areas to approximately 5° at the most exposed seagrass localities, though seagrass beds were not found at the most exposed sites. Figure 2 shows the modeled seagrass localities based on the improved criteria after the second survey (using 7° for all areas as a compromise) compared to the exact seagrass localities observed by visual inspection from the boat at night. As seen in Fig. 2, the model has a limited fit, and partially overestimated the seagrass distribution. The improved criteria was later applied and tested within the national

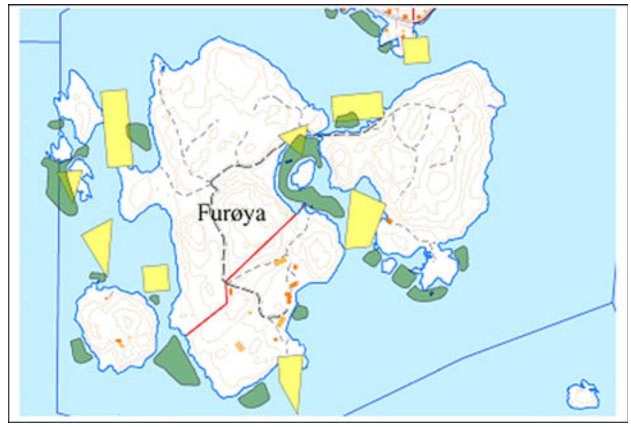

Fig. 2 Modeled seagrass localities based on the improved criteria (*yellow areas*) compared to exact distribution of seagrass observed by visual inspection from boat at night (*green areas*). For localization, see *black frame* at Furøya in Fig. 1

program for the mapping and monitoring of biodiversity, and was found to have a fit of 78.2% for the modeled area within the Skagerrak region (Longva 2006). Still, the specificity and sensitivity of the model was rather low (19 and 46.7%, respectively). The specificity expresses the number of the *modeled* seagrass areas that were found to actually contain seagrass, whereas the sensitivity expresses the number of *observed* seagrass areas that also were predicted to have seagrass.

Mud Flats

The GIS models gave very precise estimates (>90% area overlap based on interviews of local fishermen) for the distribution of mud flats (soft bottom areas). Mud flats were localized close to seagrass beds and are important nursery areas for fish (Fig. 3).

Kelp Forest

Inspections by scuba diving and video registration showed that the depth range for the offshore *L. hyperborea* kelp forest increased with exposure from about 15 m near shore to about 20 m at the most exposed sites. We also observed large areas of kelp forest on completely plain substrates in these areas. Our first suggestion of using a slope of 25° as an indication of rocky substrate with a kelp forest was not successful (Table 1). Figure 4 shows the difference in the modeled kelp forest area using the first applied criteria set based on depth and slope (Table 1) compared to the improved criteria based on a field survey in the subtidal area of exposed areas, including wave exposure in the criteria sets. The first set of criteria implies a large underestimation of the kelp forest (over 90%) in the

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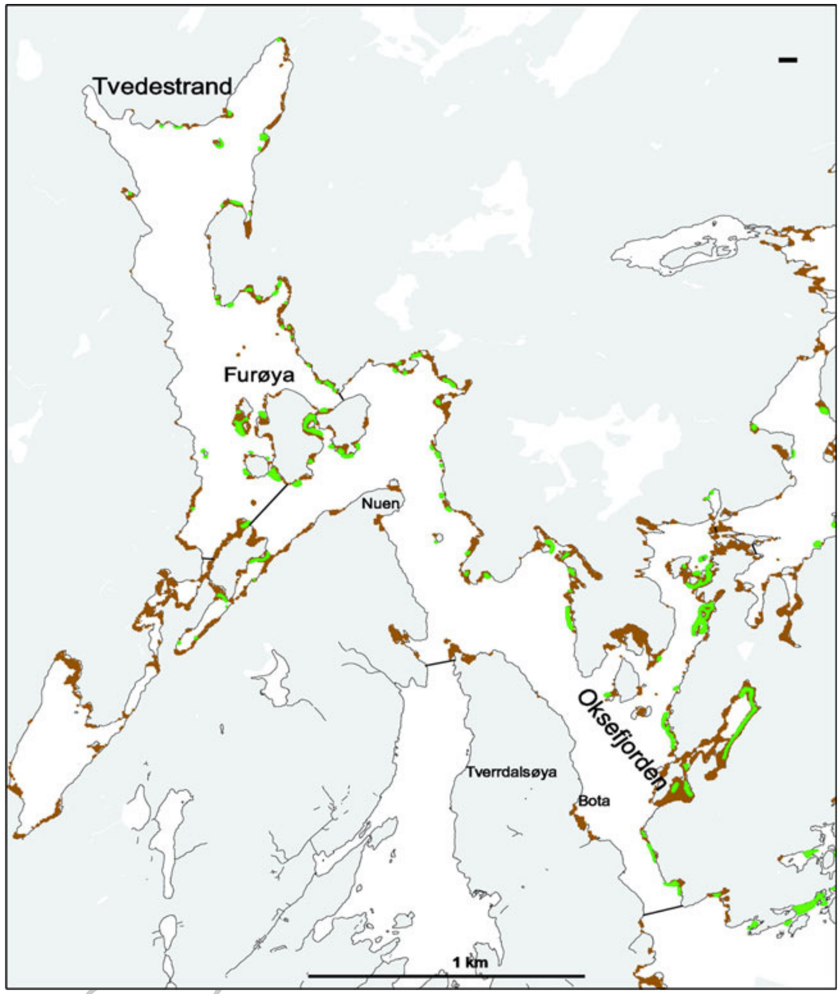

Fig. 3 Distribution of mud flats in Tvedestrandsfjord analyzed by GIS-analyses (*brown areas*), and seagrass localities (*green areas*) registered by boat surveys

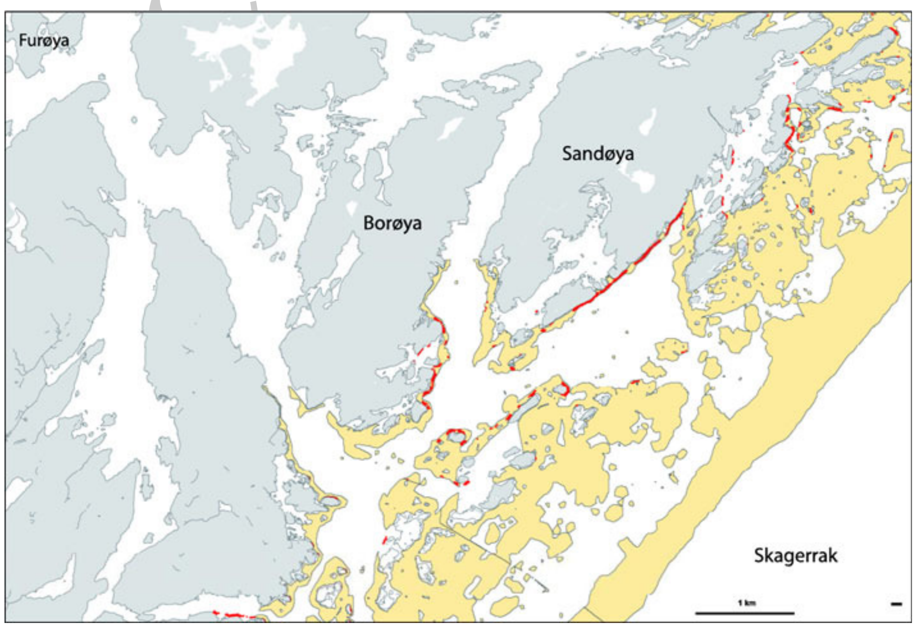

Fig. 4 Modeled kelp forest based on the improved criteria compared to old criteria. *Red areas* visualize kelp forest after old criteria, whereas *beige areas* visualize kelp forest due to new criteria

municipality by not including the large, plain area offshore, with a well-developed kelp forest down to a depth of approximately 20 m. The improved model criteria were later applied and tested in the national program for the mapping and monitoring of biodiversity, and was found to have a fit of 81.7% for the modeled area within the

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Skagerrak region (Longva 2006). The specificity of the model was 61% and the sensitivity 77.3%.

Spawning and Nursery Areas for Fish

In total, 317 cod (*Gadus morhua* L.) and 97 pollack (*Pollachius pollachius* L.) were captured within the spawning areas pointed out by the local fishermen. More than 70% of the cod and 100% of the pollack in these areas were classified as mature (Fotland et al. 2008); although pollack was only caught in the inner parts of the fjord, and are not included in Table 3. By comparison, only 22% of cod captured in the control areas outside the spawning grounds were spawning fish (Table 3). The average number of cod eggs within the spawning areas was much higher (a mean of 49.7 in the spawning areas vs. a mean of 7 in the control areas), and significantly larger than in the control areas ($t = 3.18$; $P < 0.0055$). A stratified egg sampling found that the density of cod egg was highest in the inner fjords close to the spawning areas (Table 3). Figure 1 shows the spawning areas in the Tvedestrandsfjord based upon the criteria described in the "Materials and Methods" section. A number of nursery areas were identified and designated as being active based on independent information obtained from more than two fishermen.

DISCUSSION

During this pioneering study, we have developed an approach and set of methods suitable for mapping marine habitats and fish resources on a scale appropriate for coastal zone management. For several of the habitats (e.g., spawning areas, nursery areas, and seagrass habitats), we recommend a multi-faceted approach that combines the gathering of local knowledge from fishermen and verification through scientific field sampling methods. Spawning grounds were identified by a combination of interviews, egg sampling, and test fishing. The field verification shows that experienced-based information from the interviewing of fishermen is highly reliable, as field sampling only marginally adjusted the areas reported by the fishermen. The distribution of kelp forests were well-predicted through the use of GIS models based on criteria established by field sampling across some of the most important environmental gradients for this species (i.e., depth and wave exposure; Bekkby et al. 2009). However, the seagrass models have a limited fit and partially overestimate the actual distribution of the habitat (Fig. 2), and can therefore only be used as a tool for the planning of field mapping in combination with information from local eel fishermen. For this habitat, we recommend a detailed mapping based on visual inspections from boats in the areas which are either reported to have seagrass beds based on the interviews, or based on the model are suitable for containing large areas with this type of habitat. We found that the most important nursery areas overlap to a large degree with the seagrass distribution (Jackson et al. 2001). However, kelp forests and mudflats are also important habitats for juvenile coastal fish species.

For mudflats, the GIS analysis gave a good indication of the geographic distribution, and the same approach is used in the national mapping program for marine biodiversity. However, the depth model developed and used in the national program includes elevation data for land as well as bathymetric data for the sea area, thus providing a better model for the terrain structure in the land-sea boundary than the one used in the pioneer study. In the national program, the mud flats are identified as the area between +1 m (land) and −2 m (sea) with slopes <3°. This mud flat

Table 3 Number of cod eggs observed at different localities by VP II hauls (0–30 m) during spawning period in winter, weeks 8, 11, and 14, and CPUE of fish caught close to spawning areas (the *gray dotted areas* close to localities 21–30) in the Tvedestrandfjord and off coast (control localities 31–32) during winter

Localities	Cod egg densities			Gill net sampling		
	Week 8	Week 11	Week 14	*n* (nets)	CPUE	% spaw. cod
21	7	49	149			
22	4	43	90	16	1.4	90
23	0	100	40			
24	4	13	37			
25	6	18	46	56	1.5	79.4
26	3	9	49			
27	3	5	16			
28	4	0	49	48	3.1	77.4
29	0	8	17			
30	3	12	4			
31	5		8 (week 13)	24	1.25	33.9
32	7		6 (week 13)	25	1.3	37.4

Data show number of fish nets (*n*), CPUE, percentage (%) of spawning cod (Hoek and Ehrenbaum 1911)

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model is used as a foundation for identifying mud flats through verification from aerial photographs or field sampling. Hence, the pioneer study led to the development and use of a simple method now employed for mapping mud flats along the entire Norwegian coastal zone.

The Tvedestrand area holds a unique variety of biological assets in the coastal zone, and is well-suited as a model/system for testing out various methods. Below, we discuss our results in more detail and indicate how coastal management may implement these methods and data in their future plans.

Collecting Local Knowledge Through Interviews and Field Verification

Local fishermen have prominent knowledge of marine habitats and fish resources in both the Tvedestrandfjord and offshore areas. The information gathered from the interviews about the marine habitats was verified using different methods (manual inspection from the boat during nights, scuba diving, underwater video camera, and GIS-analyses). In all the cases, there was a high degree of agreement among the results from the field sampling and the information obtained from the interviews of the local fishermen.

The classification of marine habitats based on depth, exposure, and slope was a new approach when this pioneer study was performed, and therefore needs further refinement. Nevertheless, the verification through visual inspections and diving demonstrates that this approach is useful and accurate for some of the marine habitats. Through repeated surveys planned to cover the distribution of the various habitats across the important physical gradients depth and wave exposure, the criteria for distribution were improved. The field observations showed that the distribution of seagrass beds was more random within its “fundamental niche” compared to the kelp forest. The distribution of kelp was far more predictable, which made the criteria for this habitat easier to define. The pioneer study showed that planning field sampling based on GIS-analyses and information from local fishermen are useful in identifying and delimiting important marine habitats, such as seagrass beds, mud flats, and kelp forests.

Spawning Areas

Local fishermen designated several spawning areas for fish in the Tvedestrandsfjord, which were later tested by means of scientific methods (gill net fishing, egg sampling, and echo sounding; Fig. 1; Table 3). Gill net sampling clearly identified that adult cod caught in the nominated areas inside the fjord were spawners (77–90%), whereas offshore cod were less likely to spawn (33–37% in offshore habitats; Fig. 1; Table 3). We also applied echo sounding to identify clusters of spawning fish in different sections of the fjord. Echo sounding turned out to be difficult as the bottom bathymetry was very rough within the narrow fjord and shadows prevented a meaningful interpretation of the data. Egg sampling demonstrated that a significantly higher density of pelagic eggs inside the fjord and decreasing levels further offshore (Table 3). This pattern has recently been demonstrated in a number of fjords along the Norwegian coast (Knutsen et al. 2007). The authors suggest that fjord sills play a significant role in keeping the eggs within the fjords, and are a retention mechanism that probably aids in maintaining the genetic structure among cod populations in the fjords along the coastal areas of Norway (Knutsen et al. 2003, 2004). Egg sampling is cost-effective in that it covers large areas for short periods, and allows for the identification of several species at the same time, although this method also has some weaknesses. Even though the density of the pelagic eggs will normally point out the spawning sites, i.e., the density is highest in the vicinity of the spawning grounds and the egg stages here are premature, the egg distribution may also vary considerably on a temporal scale (Espeland et al. 2006, 2007). This temporal effect could be due to variable currents forcing the dispersal of eggs and larvae throughout the spawning basin, or adult fish which move around and use more than one specific spawning site. A multi-faceted approach would therefore minimize these sources of errors. Combining information from the interviews of local fishermen with a stratified grid-based egg sampling regime and good topographic maps would thereby be sufficient in most cases for identifying the specific spawning sites for fish at inshore sections of the coastal sea.

The identification of local spawning sites in fjords is also clearly supported by recent telemetry studies (Espeland et al. 2006; Bergstad et al. 2008). Interestingly, a recent study found that the local cod populations have a difference in age and size at maturity, and in survival and growth rates, indicating locally evolved life histories on an unexpectedly small spatial scale (Olsen et al. 2004, 2008).

Nursery Areas

A number of nursery areas for fish were pointed out by the local fishermen in the fjords and offshore areas, with many of them coincident with habitats identified by the GIS-analyses or by manual surveys of habitats from boats. There was a convincing overlap among the fishermen who gave information to the project, and all were very precise about the nursery areas of fish. In general, the nursery areas designated were shallow coastal waters habitats, such as mud flats, eel grass beds, or kelp forests.

It is a challenge for all marine fish to place reproductive propagules into an environment where they are likely to

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hatch and settle into an appropriate habitat. The strategy of placing eggs in protected water masses deep inside fjords closely situated to nursery grounds may enhance the reproductive output of the fish. Obviously, fish from local spawning areas are dependent on accessible nursery grounds, as the quality and quantity of recruitment habitats may be a limiting factor for fish populations (Gotceitas et al. 1997). The importance of vegetation beds, especially *Zostera marina* and other seagrasses as an epibentic fish habitat, has been demonstrated for a wide variety of marine fishes [Gotceitas et al. 1997; Cote et al. 2001; see also review in Orth et al. (1984)]. Like seagrasses throughout the world, the eelgrass (*Zostera marina* L.) populations in Nordic waters are under great pressure (Baden et al. 2003), and human-induced disturbances and climate change are among the main factors threatening this habitat (Short and Willie-Escheveria 2000). The great loss of seagrass along the Swedish part of the Skagerrak coast within areas with the highest nutrient loads (Baden et al. 2003) gives a serious warning signal, and increases the importance of both knowing the distribution of seagrass beds and achieving a careful management of such ecologically important areas.

Important nursery areas for fish can be identified rather precisely by combining ecological information from the fishermen with the results from GIS-analyses and field sampling, which provides maps of the potential distribution of nursery habitats, such as seagrass, mud flats, and kelp forests.

CONCLUSION

The interviews with local fishermen provided knowledge acquired from centuries of catching experience in the coastal zone. Using their ecological "know how" as background information combined with scientific approaches and methods, we were able to design a sea mapping program for several habitats and fish resources along the coast.

In most cases, a multi-faceted approach was found to be the desirable strategy when testing different methods by combining a set of modern scientific approaches with the ecological information given by the fishermen. Marine habitat and resource mapping is a powerful approach and an essential prerequisite for developing an ecosystem-based and sustainable management of the coastal zone. Today, this field has been raised to a very high level of importance, both in national waters and international areas of interest (Coagen et al. 2009). This holistic approach is highly needed to meet the challenges, as biological resources in the coastal zone are under extensive pressure worldwide.

However, in the context of conservation and management issues, it is also important to distribute the marine habitat data and information to public management, so that biological resources are taken into account by the relevant stakeholders.

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