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Biological monitoring of fish and crustaceans in the Wadden Sea – potential and problems*

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ABSTRACT: Monitoring of fish and crustaceans in the Wadden Sea (WS) must cope with rapid changes in distribution patterns, access to certain areas and gear efficiency. Application and limitations of a variety of fishing devices (fyke nets, gill nets, enclosures, stow nets, purse seines, beam trawls, push nets, beach seines, bottom trawls, pelagic trawls) are discussed with regard to different objectives of monitoring. Furthermore, the validity of data from three current monitoring programmes is also discussed.

INTRODUCTION

Monitoring of fish and crustaceans may serve a variety of purposes (Fig. 1). Estimations of stock sizes in certain areas at a given time are essential for fisheries management. Furthermore, absolute numbers of animals per area are needed in ecosystem modelling, e.g. for estimation of food intake by fish and crustaceans in a given area.

Monitoring of environmental effects on organisms has increasingly gained in importance in the last decade, but more attention should be devoted to spatial and temporal differences. Determination of relative abundances is generally sufficient for assessment purposes. Estimation of infection rates with diseases and parasites, the degree of contamination with environmental pollutants, studies of ecological processes such as fertility and condition, and analysis of local faunistic structure in specific areas are examples of ecological effects monitoring.

This paper deals with difficulties that must be taken into account in sampling strategies for the monitoring of fish and crustaceans in the open and dynamic WS ecosystem. Sampling of planktonic stages is not considered.

PROBLEMS

Primarily, sampling must cope with differences in spatial distribution (Fig. 2). Spatial distribution of animals may be independent of time. Most species and size groups have a patchy distribution, which is generally determined by sediment type and water depth

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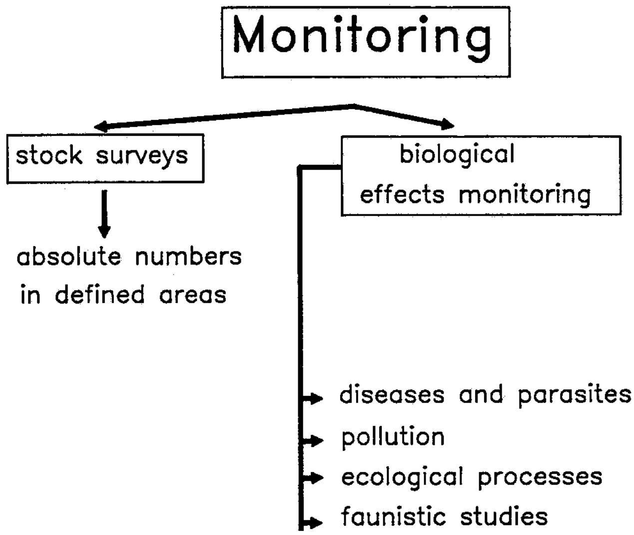

Fig. 1. Objectives of monitoring fish and crustaceans in the Wadden Sea

(Berghahn, 1987). Consequently, the research area must be stratified, and every stratum must be sampled randomly. In most cases, a large number of samples must be taken until a statistically valid measure of central tendency for a single stratum is obtained. Due to the small scale in distribution of different sediment types and depth ranges in the WS, the resulting patchiness could require an infeasible sampling effort.

Fisheries biologists in the WS are confronted with the fact that fishes and decapod crustaceans are extremely mobile, and so spatial distribution can be time-dependent due to migrations.

For example, during low tide adult flounders *Platichthys flesus* (L.) prefer the shallowest parts of the subtidal at the edges of tidal creeks and gullies, where water depth is less than half a meter (Piepenburg, 1984). They migrate onto the submerged tidal flats with the rising tide, preferring shallow areas with mixed or muddy sediments (Ruth, 1981). Several species show a similar tidal migration behaviour (Berghahn, 1987), and sampling has to be carried out in a clearly defined time interval of the tidal cycle, if it is intended to obtain absolute or at least comparable density data.

Distribution patterns are also influenced by seasonal migrations of many species inhabiting the WS – or parts of it – only for a short time of the year (Fonds, 1978). For example, grey mullet *Crenimugil labrosus* (Risso) inhabit the WS from May to October and garfish *Belone belone* (L.) enter the WS in May and leave it already in July.

Adult (2+) *Ammodytes tobianus* L. can be found on the tidal flats of the North Frisian WS at high tide only in late spring, whereas juveniles do not perform tidal migration. Some species like eel pout *Zoarces viviparus* (L.) inhabit different water depths depending upon the season. Another such example is the behaviour, and temporal and spatial distribution of plaice *Pleuronectes platessa* L. Most of the early postlarvae of plaice do not exhibit tidal migration. The time of arrival is different in the various parts of the WS. The animals stay in the tidal pools on the exposed flats during low tide, with a preference for

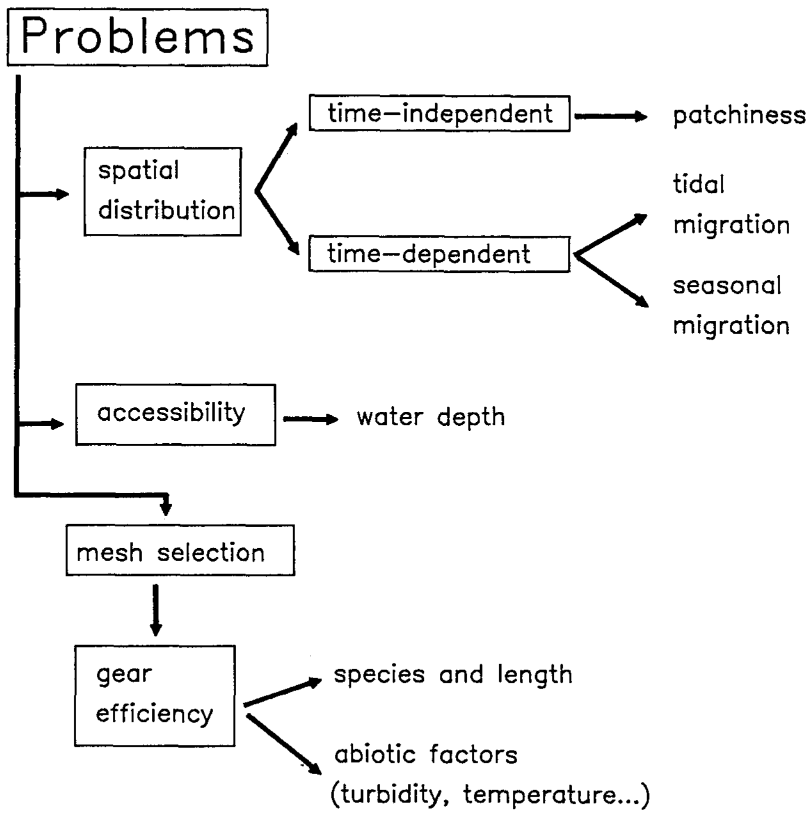

Fig. 2. Problems specific to the Wadden Sea related to sampling of monitoring data

sandy tidal flats and mixed sediments, but they can be found on mud flats, as well. A few weeks later, the major part switches to tidally phased feeding migrations, and in the course of the summer an increasing part of the population tends to permanently stay in the tidal channels and leave the WS. Some plaice juveniles also exhibit tidal migration when becoming the I-group, but not during the winter. They leave the WS in early summer. Of course, these emigrations start at different times in the various parts of the WS, depending on water temperature and the season. II-group plaice are relatively rare in the North Frisian WS, and they do not exhibit tidal migrations onto the submerged flats (Berghahn, 1987) as they do in the Dutch WS (Kuipers, 1977).

Consequently, sampling must be carried out in those areas where a species or different age groups of a species are present at a specific time of year.

This constraint leads to the next group of problems which mainly concern the process of sampling with towed gear.

For some species, reliable data cannot be obtained at all. This applies in particular to the gunnell *Pholis gunnellus* (L.), which prefers stony or mussel-covered sublittoral habitats. Extensive parts of the WS are less than two metres deep and cannot be reached with larger research vessels (cf. Fig. 2). Consequently, size and towing speed of trawled gear are also limited in areas inhabited by an important part of the mobile fauna.

However, besides mesh selection, gear size and towing speed are the determining factors for gear efficiency and resulting catch composition (Parrish, 1969). The swimming speed of fish mainly depends on length (Blaxter & Dickson, 1959; Blaxter, 1969). Trawling gear towed with a given speed will catch the small-length groups of a species more efficiently than the larger ones. For this reason, the catch has to be corrected for catching efficiency if the swept area method to obtain numbers of animals per area is employed (Kuipers, 1975). Gear efficiency must be determined separately for each species and each length group (cf. Fig. 2).

As soon as the burst speed of a length group exceeds the towing speed, members of this length group will only be caught occasionally. For these length groups no valid efficiency data and consequently no realistic numbers per area can be calculated. In this case, monitoring will fail to detect an important part of the population, or at least underestimate its size. However, gear efficiency is not an invariant parameter, even for a given species and length group. The visual stimulus from the approaching net is the main factor for fish reaction and escape behaviour (Parrish, 1969). As visual detection of a fishing device is dependent upon water turbidity, fish and crustaceans will be alarmed earlier by the approaching gear when water turbitity is low and its efficiency will be lower than in situations with high turbidity.

Water temperature (Brett, 1967) and salinity (Turnpenny, 1983) may also be of importance for fish reaction.

In any case, as shown above, there cannot be a schematic approach, neither a diagramm nor a table, to design a general sampling strategy for all species occurring in the WS. Each case (species, age group, region, season etc.) has to be considered separately. For reasons similar to those mentioned above, an intensive study on the autecology of a given species and on the specific features of the given research area must be conducted before the appropriate sampling strategy and gear can be selected. All these circumstances have to be taken into account in sampling strategies and data processing.

POTENTIAL

This chapter gives a brief overview of fishing devices and sampling strategies appropriate to the WS, including applications and limitations. The influence of mesh selection on the catch has to be taken into account with every individual type of gear.

First, we may distinguish passive and active gear. The principle of passive gear is that the animals come to the gear, while active gear is towed over an area, catching normally an unknown part of the animals inhabiting this "swept area".

All types of passive gear (Table 1) generally have the disadvantage of being useable once per tide. Therefore, the extent of the research area is limited by effort. In addition, seasonal migration of species does not allow the employment of passive gear in different areas successively, as there will be a longer time lag between sampling dates. In the most cases, it is impossible to obtain the absolute numbers per area necessary for stock assessment. Catch per unit effort data can be used to obtain information about differences in population densities between different delimited areas.

Fyke nets, similar to the gear used by Hinz (1983), are suitable for catching animals migrating through an area in which these nets are installed. They can be employed at any water depth to catch demersal fish and crustaceans with low selectivity, but absolute

Table 1. Passive gear applicable in the Wadden Sea

	Range	Objects	Selectivity	Area	Use
Fyke nets	>0 m	DF, C	low	no	D, P, E, F
Gill nets	>0 m	DF, PF	high	no	D, P
Enclosures*	<2.5 m	DF, PF, C	low	yes	S, D, P, E, F
Stow nets	<20 m	DF, PF	medium	no	D, P, F
Purse seines	>10 m	PF	low	yes	S, D, P, E, F

EC = efficiency data required; DF = demersal fish; PF = pelagic fish; C = Crustaceans; S = stock survey; D = diseases; P = pollution; E = ecological processes; F = faunistic studies; * = only applicable on tidal flats

numbers per area cannot be estimated with the method. Principally, fyke nets are useful for biological effects monitoring.

Gill nets also catch migrating fish, and they can be employed at any depth, but only a few length groups appear in the catch, depending on mesh size. Selectivity is extremely high (Boy & Crivelli, 1988), in comparison to fyke nets. Gill nets catch demersal fish, as well as pelagic fish. Again, estimates of absolute fish densities are not possible. Gill nets are useful for collecting samples for determining contamination with environmental pollutants and the degree to which fishes are infected with diseases and parasites, but the use of this gear is labour-intensive and demands some experience in waters with strong tidal currents (Stewart, 1988).

Enclosures can be employed on tidal flats (Hellier, 1958; Kuipers, 1975; Ruth, 1981) but not in sublittoral areas. They are the only possible method for quantitative sampling in areas with mussel beds and gravel. Enclosures can catch fish and crustaceans migrating into the sampling area later enclosed at high tide. No selection apart from mesh selection occurs, and the numbers of animals caught are a direct measure of density. For this reason, enclosures meet all requirements of monitoring purposes on tidal flats.

Stow nets (Brand, 1984) are efficient in catching migrating animals in rivers (Möller, 1988) and tidal channels down to twenty metres of water depth. Selectivity depends on the obstruction in front of the net opening, resulting from mesh size and current velocity. Mainly demersal and pelagic fish are caught. Absolute numbers per area cannot be obtained. Stow nets are suitable for monitoring diseases and parasites, pollution and faunistic composition.

Purse seines can only be used in the water column in water depth greater than 10 m. Only mesh selection takes places. Pelagic fish are caught effectively, but estimations of population size can only be carried out in connection with echo surveys. Handling this gear is difficult in the WS due to the limited areas with adequate water depths greater than 10 m, and due to the strong tidal currents (Levings, 1982).

The next group of gear is towed gear, or so-called active gear (Table 2).

If the gear efficiency is known, all types of this gear can be used for swept area calculations and biological effects monitoring. Limiting factors are the towing speed and the accessibility of the different areas. Apart from beach seining in the tidal gullies during

Table 2. Active gear applicable in the Wadden Sea

	Range	Objects	Selectivity	Area	Use
Push nets	<1 m	DF, C	high	EC	S, D, P, E, F
Beach seines	<2 m	DF, PF, C	medium	EC	S, D, P, E, F
Small beam trawls	>1 m	DF, C	high	EC	S, D, P, E, F
Young fish trawls	>1 m	DF, C	medium	EC	S, D, P, E, F
Beam trawls (shrimps)	>2 m	DF, C	medium	EC	S, D, P, E, F
Bottom trawls	>5 m	DF, C	low	EC	S, D, P, E, F
Pelagic trawls	>20 m	PF	low	EC	S, D, P, E, F

EC = efficiency data required; DF = demersal fish; PF = pelagic fish; C = Crustaceans; S = stock survey; D = diseases; P = pollution; E = ecological processes; F = faunistic studies

low tide, several hauls can be made at relatively short time intervals during one tide. In all cases, sampling cannot be carried out in areas with mussel beds, gravel and moving sands.

Push nets (Riley, 1971) can be used in a water depth down to one metre, catching mainly small demersal fish and crustaceans. Beach seines should preferably be employed to analyze populations in small gullies and creeks with water depths down to two metres (Piepenburg, 1984).

Small beam trawls are restricted to water deeper than one metre, due to disturbance by boat and motor (Kuipers, 1975; Berghahn, 1986). They serve for all monitoring purposes for small fish and crustaceans, particularly on tidal flats. The same applies to young fish trawls, which have a greater efficiency due to herding effects, but are more difficult to handle (Johansen, 1922; Gibbs & Matthews, 1982).

Beam trawls used by shrimpers catch demersal fish and crustaceans in waters deeper than two metres (Meyer Warden & Tiews, 1965; Tiews, 1971, 1983). They have an intermediate selectivity mainly caused by water obstruction in front of the gear. The best suited areas are tidal channels and streams during the entire tide cycle.

Bottom trawls are comparable to large beam trawls, but they are more effective due to their herding action.

Pelagic trawls might be used in a water depth greater than 20 m. All monitoring objectives can be achieved for pelagic fish.

EXAMPLES

In terms to fishing gear, sampling for effects monitoring does not cause serious problems unless absolute density data are required, e.g. in investigations of the total predation on macrozoobenthos organisms by fishes in a given area. The spatial distribution of the target animals must be considered before gear and sampling strategy are selected, depending on sediment and tidal and seasonal migration. It is unreasonable, for example, to study diseases and parasites of adult flounders in the WS on the basis of catches from shrimping vessels, because these ships cannot reach the shallow areas preferred by flounders during the summer. Consequently, only very few adult flounders are caught by shrimpers, and sampling effort and costs to obtain adequate numbers of

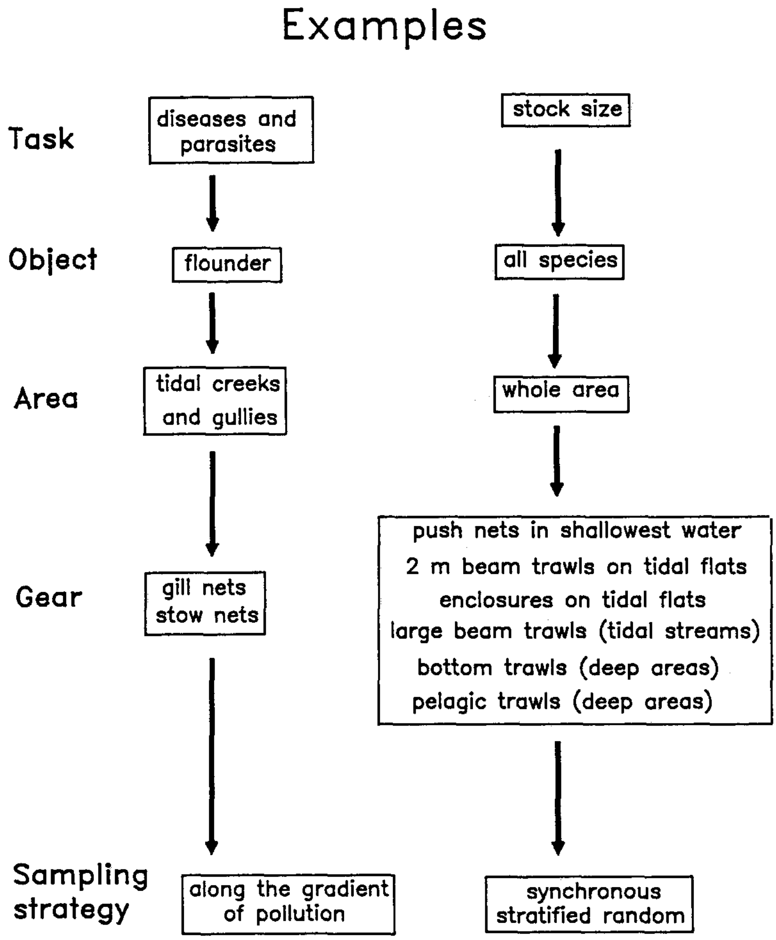

Fig. 3. Examples of sampling gear and strategies in the Wadden Sea

animals will be very high. Sampling with gill nets, large fyke nets or stow nets in the tidal creeks and gullies would be more appropriate (Fig. 3).

Estimating absolute numbers per area is the most difficult task. One of the recent monitoring programs, the International Demersal Young Fish and Brown Shrimp Survey (DYFS), conducted from 1969 to the present, monitors relative abundance of young fish and crustaceans in the WS and the adjacent coastal area of the North Sea in spring and autumn every year (Dankers & de Veen, 1978). 3-m and 6-m beam trawls, rigged with bobbin rope and one single tickler chain are in use. Generally, these monitoring data cannot be used as absolute numbers, due to the fact that tidal phases are not taken into consideration and the area swept is restricted to depths below 2 m (Berghahn, 1986). Consequently, absolute numbers can only be estimated for species without tidal migration behaviour and mainly living in the depth range investigated, such as juvenile dab *Limanda limanda* (L.), even if the gear efficiency is known. However, the results concerning other species might be used as indices to compare different regions or years. Furthermore, these indices for juvenile sole *Solea solea* (L.) and juvenile plaice have recently been related to virtual population analysis (VPA) data (van Beek et al., 1989). This is nevertheless only valid, if the major part of the population inhabits the area actually swept. Due to the limitations of the DYFS gear, similar estimations for species like flounder (water depth!), herring *Clupea harengus* L. or sprat *Sprattus sprattus* (L.) (pelagic fish!) are not convincing.

The by-catch from the German shrimp fishery has been studied by the Institute for Coastal and Inland Fishery of the German Federal Fishery Research Agency since 1952 (Meyer Waarden & Tiews, 1965; Tiews, 1971, 1983). Some effort has been made to increase the goals of this program by simply computing by-catch data into absolute numbers. The basic assumption was that the by-catch of the shrimp fishery is about one third of the standing stock in the German WS. Furthermore, this was supposed to be true for all species (Tiews, 1971, 1983). However, these assumptions are not likely to meet reality, due to the fact that these by-catch samples are not taken in a stratified manner, and temporal and spatial changes in distribution patterns are not taken into account.

In order to obtain absolute numbers from by-catch samples, sampling has to be stratified, randomized and synchronized in a very short period of the season. All catches have to be carried out at low tide. The time interval of the investigation should not exceed one week, due to seasonal migration. This kind of sampling design has to be complemented by means of synchronized push netting in shallow areas, beam trawling at the edges of the tidal channels between 1- and 2-m water depth with a small beam trawl, and beach seining in representative tidal creeks and gullies (Fig. 3).

Moreover, the efficiency of all gear types employed must be assessed. The costs of such a strategy might be high, but we suggest that this approach is the only practicable way to obtain realistic density data for management purposes.

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