Ecological effects of potential oil spills at the German North Sea coast

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Introduction

The Wadden Sea, a region of tidal flats and salt marshes extending at the North Sea coast of the Netherlands, Germany and Denmark, is of enormous value as a cleansing site for North Sea water, as a nursery for young fish, and as a feeding ground for many bird species. The Netherlandish and German part of this region is especially endangered by oil spills due to the proximity of important shipping routes and harbours. The permanent danger of oil spills caused by tanker accidents has been recently demonstrated by a series of three big accidents within 6 weeks: the »Aegean Sea« at the Spanish coast in December 1992, the »Braer« near Shetland and the »Maersk Navigator« in the Strait of Malacca in January 1993.

This study documents the ecological effects of potential oil spills on the ecosystems of the German North Sea coast. First we discuss the reasons for the high oil sensitivity of the Wadden Sea reviewing the results of experimental field studies and studies conducted in mesocosms. In the second part special emphasis is paid to quantities of oil causing disasterous long-term effects to the Wadden Sea ecosystems. The effects of different amounts of oil spilled are illustrated by two simulations produced by an operational oil dispersion model.

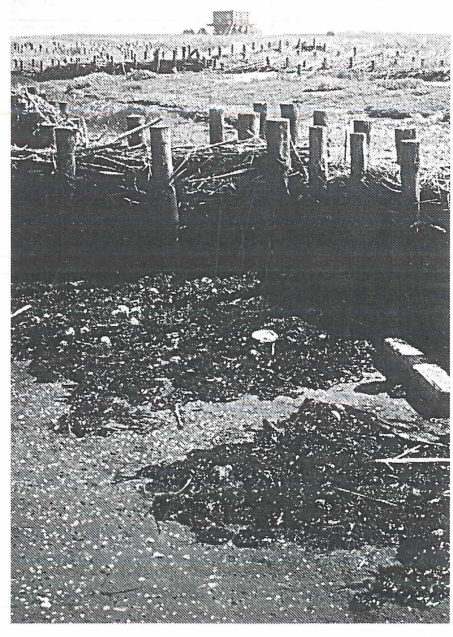
Environmental oil sensitivity of the Wadden Sea

According to the vulnerability index of GUNDLACH & HAYES (1978) based mainly on geological and sedimentological parameters, sheltered tidal flats and salt marshes belong to the coast types most sensitive to oil pollution. Oil persists very long in fine sediments exposed to low wave energy. As most parts of the Wadden Sea are dominated by these habitat types the whole German North Sea coast can be classified as highly sensitive to oil spills. As it is not possible to protect the whole German North Sea coast at equal levels, oil spill contingency planning requires a more detailed classification of the Wadden Sea. For this reason the entire German part of the Wadden Sea has been mapped according to oil spill sensitivity. This sensitivity assessment integrates biological information to an essentially greater extent than the work of GUNDLACH & HAYES (1978). Species of halophytes, mammals, fishes, birds, macrofauna, meiofauna and microphytobenthos were evaluated and classified according to their vulnerability to oil pollution. The project is described in detail by van BERNEM (1992).

Making use of the synchronously developed WATIS data processing system, a basis has been established not only to serve scientific purposes but also to designate representative sampling areas as part of a monitoring program for the entire region, to directly provide preventive and remedial measures for combatting oil pollution and for environmental protection.

The sensitivity of Wadden Sea organisms to oil pollution has been demonstrated by field experiments and research using mesocosms, large tanks situated on land or bag systems placed »in situ« containing realistic marine population assemblages.

Some members of the benthic macrofauna are very vulnerable to oil pollution. Small scale oil contaminations of intertidal areas in the Jade (German Bight) showed that especially on mud flats the populations of *Macoma balthica, Heteromastus filiformis* and *Tubifucoides benedeni* were badly affected while the amphipods nearly vanished from the contaminated area (RACHOR 1984). A breakdown of the population of the amphipod *Corophium volutator* having been repeatedly contaminated with small oil doses was observed in experiments in the Elbe estuary (van BERNEM 1982). DEKKER & van MOORSEL (1987) studied the effects of oil pollution on intertidal mudflats using mesocosms. The molluscs *Cerastoderma edule* and *Macoma balthica* showed high mortalities when exposed to large doses of oil. Additionally, *C. edule* suffered an increased mortality during severe frost periods compared to the unoiled controls. Pollution induced stress seems to increase susceptibility to unfavourable environmental conditions. The same high oil doses sufficient to cause some acute mortality of the molluscs eliminated the population of *C. volutator* without recovery afterwards. This high sensitivity of amphipods to oil pollution has been confirmed in many experiments and field studies. Reduced feeding activity of some macrofauna species having been exposed to oil was one result of mesocosm experiments conducted at the coast of Lower Saxony (FARKE et al. 1985).



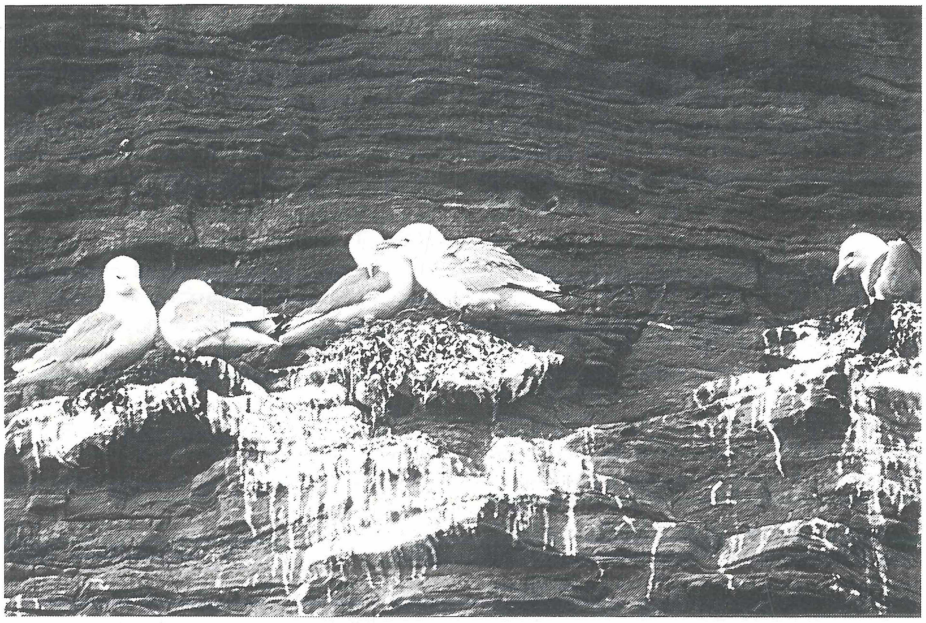
The regeneration of severely affected areas by oil, here near the tern island Norderoog, may take years or even decades.
Foto: Archiv Verein Jordsand

Species of small benthic organisms as diatoms, ciliates, turbellarians, nematodes and copepodes also were affected by oil in field experiments conducted in the Wadden Sea (DÖRJES 1984). Their ability to recover is assessed generally to be greater than that of the sensitive macrofauna species.

The high sensitivity of saltmarsh vegetation to oil pollution has been demonstrated by serveral field experiments also conducted at the German North Sea coast (for example JITTLER-STRAHLENDORFF & NEUGEBOHRN 1989). Grazed saltmarshes are more vulnerable to oil than ungrazed ones because oil washed ashore is hardly retained by the vegetation and penetrates deep into the soil where subterranean plant organs and soil fauna are affected.

The possible effects of a large oil spill covering extensive parts of the German North Sea coast is not known exactly until now as there are no appropriate experiences with big oil spills within this area. The results of experiments conducted in the Wadden Sea and of investigations of oiled tidal flats in the Persian Gulf region suggest the following phenomena:

– Burrowing species are of special importance for maintaining the ecosystem in tidal flats. They rework the sediment, flush overlying water in and out, cause sediment oxygenation, enhance nutrient fluxes, maintain bacterial gardens and provide a variety of microhabitats for other small animals (REISE 1990). Whereas oil hardly penetrates into water saturated mudflats, the tubes of burrowing animals allow oil to deeply penetrate into the sediment (HOWARD & LITTLE 1987). Due to toxic effects of the oil, populations of especially sensitive species (like the amphipod *Corophium volutator*) may break down. The burrowing activity would stop and consequently the stability of the oil



An oil spill near Helgoland during the breeding season of the kittiwakes may lead to the wipe-out of the colony. Foto: Archiv Verein Jordsand

layers and the missing oxygen will hinder a greater amount of biodegradation in the sediment. The persistence of the oil will delay recolonization of the contaminated sediment by burrowing macrofauna species (Heiber 1985). This expectation is confirmed by investigations of Höpner et al. (1993) showing no essential recolonization of oil covered tidal flats at the Saudi Arabian coast by the most important burrowing species (the crab *Cleistostoma sp.*) after one year. In mesocosm experiments reviewed by Scholten & Kuiper (1988) acute mortality of benthic fauna was often followed by an increase of micro-algal biomass because the reduction of grazing pressure exceeds the inhibition of the primary production. The high amount of now available food causes an explosive development of rapidly growing small opportunistic species. These small species like the polychaet *Capitella capitata* live right beneath the sediment surface and their contribution to bioturbation is relatively low compared to the larger burrowing species. Although the species most important for bioturbation in sand flats, *Arenicola marina,* is reported to be of little sensitivity to oil by several investigators (i.e. Gordon et al. 1978), other studies showed reduced feeding and leaving of contaminated sediments (Levell 1976, Prouse & Gordon 1976). So severe oiling of the sediment may essentially reduce bioturbation by *A. marina* on sand flats whereas this species may be very important for biodegradation in moderately oiled sediments (Greiff & Hartwig 1985).

– Long-term effects of oil contamination can arise from the reentry of largely unweathered oil from the sediment into the water column, where it may again cause mortality of sensitive organisms. Sources for this kind of chronic oil pollution may be mussel banks and shell deposits which act as sinks for stranded oil. Even two years after the oil spill of the »Exxon Valdez« in Alaska, high concentrations of oil have been recorded in the sediments beneath mussel banks and within the mussels itself which may be responsible for the low reproductive success of mussel feeding animals like harlequin ducks (*Histronicus histronicus*) and oystercatchers (*Haematopus bachmani*) (Babcock et al. 1993).

– Further long-term effects may be caused by accumulation of especially toxic high-boiling polycyclic aromatic hydrocarbons in the sediments (van Bernem 1984).

– A long-lasting breakdown of populations of benthic invertebrates after an oil spill would present a serious threat to birds searching for food in the Wadden Sea. There are some indications that feeding areas for waders using the West-European flyway are so limited that even minor reductions will result in decreasing populations of these species (Andersen-Harild 1987). Only about half as much waders as in the year 1986 were observed in the winter of the year 1991 after the oil pollution of the Saudi Arabian coast during the Gulf war (Ewans et al. 1993). A reduced food supply following the oil spill seems to be the probable cause for the strong decrease in the number of passage migrants at the Saudi Arabian coast in winter. Extensive mortality of birds at the North Sea coast by direct contact with floating oil can be expected in the following cases (Reineking 1987): 1) Oil spill near Helgoland or near a tern colony during the breeding season; 2) Oiling of moulting shelducks (*Tadorna tadorna*) in August; 3) Oil spill in a cold winter when lakes and rivers are covered by ice; 4) Oil spill at the time of high densities of passage migrants. A rehabilitation of oiled birds may be recommendable from an ethic point of view but will hardly diminish the harmful consequences for the populations of the bird species involved (Vauk 1984).

– Fishes may be affected by the acute toxicity of the oil or by food limitations as well when populations of their invertebrate prey organisms decrease. Many fish species of the North Sea use the Wadden Sea as a nursery so that a large oil spill in this region might have severe and long-lasting repercussions of the fisheries production of the southern North Sea (Dethlefsen & Tiews 1985). Results of investigations of Conan & Friha (1981) after the »Amoco Cadiz« oil spill showed that especially benthic flat fishes which are common in Wadden Sea areas suffer from oil polluted sediments.

– Following the oil spill of the »Braer« in Shetland strong winds carried the light crude oil many kilometers inshore polluting meadows and houses. The same phenomenon might be observed in the case of an oil spill in the Wadden Sea with a light crude oil and strong inland winds. Severe damages to the vegetation of dikes due to spraying of oil has been demonstrated in experiments. (Jittler-Strahlendorff 1984).

A further reason for the sensitivity of the Wadden Sea is the difficulty of removing the oil spilled. The use of dispersants cannot be recommended because the effects of chemically dispersed oil are even worse than the effects of untreated oil (Dörjes 1984). Since heavy machines can't be used in tidal flats the oil has to be removed using light machines and manpower. Negative consequences of mechanical cleanup activities in saltmarshes have been demonstrated by geomorphological changes following the removal of oiled sediments by heavy machines in Brittany after the »Amoco Cadiz« oil spill (Vandermeulen et al. 1981). With respect to these experiences and own experiments Jittler-Strahlendorf & Neugebohrn (1989) recommend to use only light machines and to applicate roll-on grass stripes for the recovery of oil polluted salt marshes.

Similar effects as described in this chapter are expected by Anderson-Harild (1987) in the case of a major oil spill in the Danish Wadden Sea:

– a reduced density of the microfauna and -flora and of the invertebrates of the tidal flats probably lasting for 5–10 years,

– a reduction in the number of fish using the area due to direct mortality and reduced food-resources,

– a change and possible destruction of the vegetation on the salt marshes,

– direct mortality of waterfowl in and near the Wadden Sea.

Effects of oil spills in the Wadden Sea in relation to the quantity of spilled oil

It is difficult to delimit the amount of oil which can cause catastrophic effects to the ecosystems of the Wadden Sea because the extent of the ecological effects depends on many interacting factors: the type of oil, the meteorological situation and the density of sensitive organisms at the time of the oil spill, vulnerability of the coastline affected and the clean-up measures applied. The relationship between the amount of oil spilled and the dimension of the effects can be illustrated by analysing two examples of simulated oil spills as follows:

The perhaps most probable szenario of a big oil spill at the German North Sea coast is an accident near the most important German oil-terminal Wilhelmshaven. Using the results of the operational oil dispersion model of the »Bundesamt für Seeschiffahrt und Hydrographie (BSH)« described by DICK & SOETJE (1990) two examples of simulated oil spills in this region with different quantities of released oil are compared. In this part of the North Sea the main wind direction is south-west so that Dithmarschen and Eiderstedt at the coast of Schleswig-Holstein are especially endangered. The two cases discussed below are no real events but fictive scenarios arbitrary chosen from a number of examples of oil spills simulated by the above mentioned model.

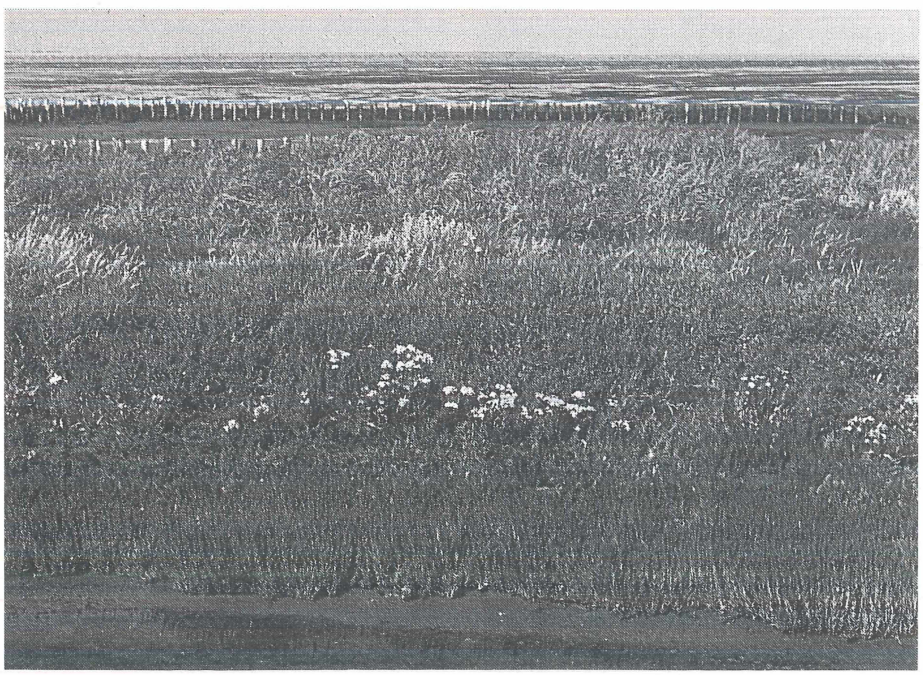
The first case is probably what may be called the worst case of a tanker accident imaginable at the German North Sea coast. A tanker breaks down in the Jade near Wilhelmshaven and 40500 t No. 2 fuel oil are spilled. Strong winds from south-west drive the oil slick first to the coasts of the islands of Neuwerk, Scharhörn and Nigehörn where colonies of endangered tern species are situated. The heavy weather hinders any effective cleanup measures. Later the oil reaches the island of Trischen, and Dithmarschen and Eiderstedt at the coast of Schleswig-Holstein. Especially Trischen and its surrounding are highly important as a breeding ground of terns, a moulting place of shelducks and a resting place of waders (PROKOSCH 1987). Finally a part of the oil pollutes the Northfriesian Islands. An oil spill during the breeding season of the terns may lead to the wipe-out of the affected colonies. Another consequence would be a break down of the populations of sensitive benthic invertebrates in wide areas of the Wadden Sea of Schleswig-Holstein. Since oil is expected to persist in the sediments of tidal flats for many years preventing the recolonization by the benthic fauna, this part of the Wadden Sea will be no longer suitable as a nursery for fishes and as a feeding ground for birds for a long time. The regeneration of the severely affected areas may take years or even decades.

The second case reported here is a tanker accident at the East Friesian Islands and the release of 6000 t oil (IFO 450). Wind from north-west drives the oil slick to the islands of Neuwerk, Scharhörn and Nigehörn. Finally the oil reaches the coast of Dithmarschen in Schleswig-Holstein. As stated above, the oiling of the affected islands during the breeding season of the terns would be detrimental to the populations of these rare bird species. Compared to the first case the effects on benthic invertebrates would be spatially delimited due to the minor amount of spilled oil and the less strong winds. It can be expected that the consequences of this accident with some 1000 t spilled oil does not reach by far the catastrophic dimensions of the first case with some 10000 t of spilled oil.

Although the two examples differ in some geographical and meteorological aspects they seem suitable to illustrate the importance of the amount of spilled oil in relation to the dimension of the effects. High densities of sensitive organisms like moulting birds or young fish might be severely affected by even small amounts of oil. On the other hand a large amount of oil may have little effects if only a minor part of the oil is washed ashore. But only a large oil spill may reach the catastrophic dimension shown by the first example.

A special relationship between the extent of the oil coverage and the quantity of oil washed ashore has been confirmed for tidal flats. If only a small amount of oil reaches the coast the oiling is limited to the high water level. However, if a large quantity of oil is washed ashore, the sediment at the high water level is soon saturated and an oil layer will cover the related intertidal zone. Such an oil coverage of entire tidal flats has been observed at the Saudi Arabian coast after the Gulf war (van BERNEM 1992).

Using the results of the sensitivity mapping of the German North Sea coast it may be possible to protect most vulnerable parts of the Wadden Sea in the case of an oil spill. The success of oil spill control measures, however, depends strongly on the amount of spilled oil. The equipement for oil spill control at the German North Sea coast is sufficient to handle oil quantities until 15000 t at normal weather conditions (BUSTORFF 1992). If a big oil spill happens under heavy weather conditions the success of control measures may be very limited and the results of the sensitivity mapping can only be used for ecological impact assessment.



Saltmarsh vegetation, here on the island Norderoog, has a high vulnerability to oil pollution.
Foto: Archiv Verein Jordsand

Conclusions

The Wadden Sea at the German North Sea coast is of enormous value as a unique and relatively undisturbed natural area within Europe. This ecosystem is highly sensitive to oil pollution and at the same time threatened by the possibility of a big oil spill. A tanker accident with the release of some 10000 t oil may lead to ecological long-term effects of catastrophic extent. The loss of some 1000 t of oil may cause serious consequences but the affected area will be significantly smaller. Very dense populations of sensitive species might be affected by much smaller quantities of oil. However, the ecological impact of an oil spill is influenced by several factors of which the quantity of spilled oil is only one, although very essential.

Beside the ecological impact a large oil spill may cause considerable economic losses especially to tourism and fisheries. REINKE et

al. (1989) assessed the economic loss following a severe oil spill contaminating the Wurster Watt in Lower Saxony to be about 120 million DM. The costs of an oil spill as described in the first example would be at least about 10 times of that grant.

The success of oil spill control measures will be quite ineffective if a large amount of oil is lost under bad weather conditions. The probability of a tanker accident might be reduced by declaring the Wadden Sea a »Particular Sensitive Area« according to the International Maritime Organization (IMO), if additional effective measures suitable for improving the safety of individual ships and the ship traffic are considered. The only safe way to prevent an ecological disaster in the Wadden Sea is to reduce the quantity of oil transported by single tankers with additive modifications of the construction of oil tankers which reduce the probability to lose great portions of their cargo. The risk of destruction of great parts of the unique ecosystem »Wadden Sea« is no longer acceptable.

Summary

The Wadden Sea at the German North Sea coast is both of international importance for nature conservation and of high sensitivity to oil pollution. The sensitivity of the tidal flats is caused by the long persistence of oil in the sediments of low grain size, the chronic oiling by nearly unweathered oil deposited in the sediments following the spill reentering the water column and the slow biodegradation of the oil in the sediment after bioturbation of burrowing organisms has stopped due to the toxicity of the oil. Beyond this, high densities of very vulnerable birds and young fish occur at certain times in the Wadden Sea. Two simulations of oil spills in the Wadden Sea illustrate the dimension of the expected effects in relation to the amount of spilled oil. A tanker accident accompanied by the release of some 10000 t oil may lead to long term effects of catastrophic extent. Experiences from the oiling of tidal flats during the Gulf war showed that a special relationship exists between the extent of the oil layers and the amount of stranded oil. If relatively few oil reaches the coast only the sediments at the high water level are oiled whereas great quantities cause the distribution of oil in the related intertidal zone. It is suggested to reduce the amount of oil transported by a single tanker in order to prevent an oil spill of catastrophic dimensions in the Wadden Sea.

Zusammenfassung

Ökologische Auswirkungen von potentiellen Ölunfällen an der deutschen Nordseeküste

Das Wattenmeer an der deutschen Nordseeküste ist sowohl von internationaler Bedeutung für den Naturschutz als auch von großer Empfindlichkeit gegenüber Ölunfällen. Die Sensitivität des Wattenmeeres ist zurückzuführen auf die Persistenz des Öls in den feinkörnigen Sedimenten, die chronische Ölverschmutzung durch Freisetzung von nach dem Unfall im Sediment abgelagertem Öl und die langsame Biodegradation des Öls im Sediment, nachdem die Bioturbation durch grabende Benthosorganismen wegen der toxischen Wirkung des Öls unterbleibt. Zudem finden sich zu bestimmten Zeiten hohe Konzentrationen verwundbarer Organismen wie Vögel und Jungfische im Wattenmeer. Zwei Simulationen von Ölunfällen werden benutzt, um das Ausmaß der Auswirkungen in der Abhängigkeit von der Menge des freigesetzten Öls zu illustrieren. Ein Ölunfall mit mehreren 10000 t Öl kann zu Schäden von katastrophalen Dimensionen führen. Erfahrungen nach dem Golfkrieg zeigen speziell für Wattenküsten einen Zusammenhang zwischen Ausdehnung der Verölung und der Menge des gestrandeten Öls. Geringe Ölmengen führen nur zu einer Verschmutzung des Spülsaumbereiches, während große Ölmengen zu einer Verschmutzung des benachbarten Eulitorals führen. Es wird vorgeschlagen, das Risiko eines Ölunfalls mit katastrophalen Auswirkungen zu vermindern, indem die durch einzelne Tankschiffe transportierten Ölmengen begrenzt werden.

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A long-lasting breakdown of populations of benthic invertebrates, e.g. lugworms, after an oil spill would present serious threat to birds searching for food in the Wadden Sea. Foto: Archiv Verein Jordsand

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Die Vögel Bremens und der angrenzenden Flußniederungen

536 S., mit 38 Farb- und 11 SW-Abbildungen, Format 25 x 17 cm; ISBN 3-9802876-0-2. Hrsg.: BUND Landesverband Bremen, Am Dobben 44, 28203 Bremen; Preis: DM 48,–.

Die Erforschung der Vogelwelt in Bremen hat eine lange Tradition. Mit dem vorliegenden Buch soll diese fortgesetzt und eine Lücke zu der letzten Brutvogel-Erfassung von 1962/1963 geschlossen werden. Etwa 290 im Bremer Gebiet nachgewiesene Vogelwarten werden behandelt. Für die Darstellung des jahreszeitlichen Auftretens wurden allein aus den Jahren 1971–1988 rund 12000 Beobachtungslisten ausgewertet; das Brutvorkommen (bis 1990) und der Durchzug werden u. a. anhand von 63 Verbreitungskarten und 84 Diagrammen sowie zahlreichen Tabellen dargestellt.

Der allgemeine Teil des Buches gibt neben einer landschaftsökologischen Beschreibung des Bremer Raumes einen historischen und einen nach Naturräumen gegliederten Überblick der Vogelwelt Bremens. Ein weiteres Kapitel stellt die Gefährdung der Bremer Vogelwelt und die notwendigen Schutzmaßnahmen dar.

Den Verfassern ist mit der »Avifauna Bremens« ein wichtiges Nachschlagewerk gelungen, das das umfangreiche Beobachtungsmaterial überschaubar zusammengefaßt hat. Eike Hartwig

PROBST, Wilfried & Karl SCHILKE (1994):

Natur erleben – Natur verstehen

176 Seiten mit vielen graphischen Abbildungen; ISBN 3-12-0433110-9. Ernst Klett Schulbuchverlag, Stuttgart. Preis: DM 40,–.

Dieses Buch gestaltet den naturwissenschaftlichen Unterricht einmal anders: Aus der Vielfalt der möglichen Beziehungen zwischen Mensch und Natur werden mit der Aufforderung »Natur erleben – Natur verstehen« zwei Aspekte herausgegriffen, von denen der erste für Gefühl, sinnliche Erfahrung, ganzheitliche Wahrnehmung, der zweite für Intellekt und kausale Erklärung steht. Die Autoren regen dazu an, erst zu erleben und zu erfahren und dann zu analysieren, zu bestimmen und zu beschreiben.

Die in diesem Buch vorgeschlagenen Aktivitäten können zu allen Jahreszeiten durchgeführt werden, wobei sicher das Sommerhalbjahr etwas günstiger ist, und es werden außerdem unterschiedliche Orte des Erlebens einbezogen, so z.B. Park, Wald, Schulgarten, Ödland und Meeresstrand. Die 19 Kapitel, die den Themenkreisen »Die Welt erleben«, »Pflanzen im Naturkreislauf«, »Spurensuche in der Natur« und »Die Natur im Jahreslauf« zugeordnet werden, sind in folgende Abschnitte eingeteilt: Was man wissen sollte, was man vorbereiten und bedenken muß, was man braucht, es geht los, Vorschläge für weiterführende Fragen und Literatur.

Dieses Buch ist für den fächerübergreifenden naturwissenschaftlichen Unterricht und den biologischen Fachunterricht bestimmt und mit kopierfähigen Arbeitsblättern ausgestattet. Eike Hartwig