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THE SEA BIRD WRECK IN THE IRISH SEA, AUTUMN 1969.(U)
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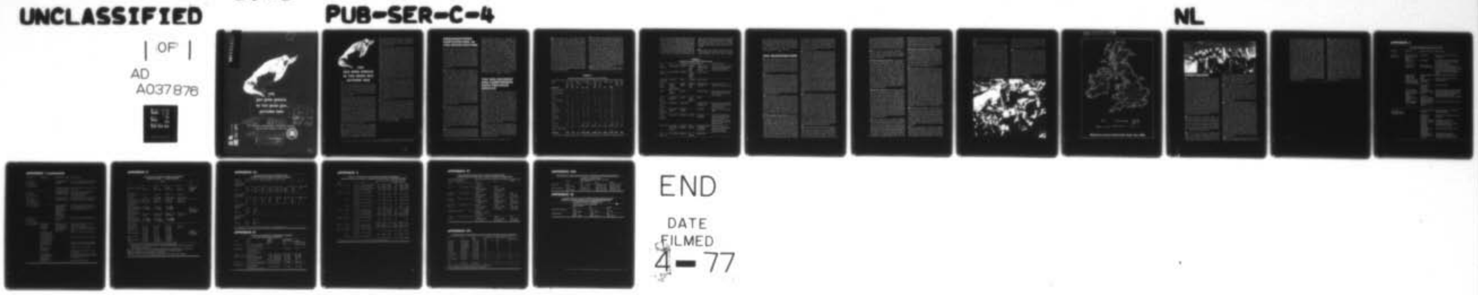

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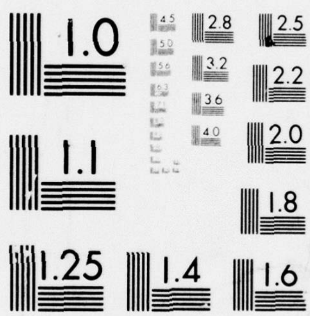

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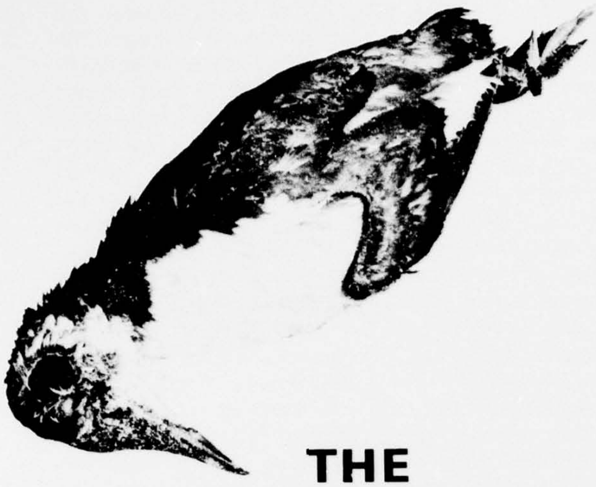
THE SEA BIRD WRECK IN THE IRISH SEA, AUTUMN 1969.

THE NATURAL ENVIRONMENT RESEARCH COUNCIL
PUBLICATIONS SERIES C No4 1971



THE SEA BIRD WRECK IN THE IRISH SEA AUTUMN 1969

1 This report is about the deaths of over 12,000 sea birds, mostly guillemots, which were washed up on the shores of the Irish Sea and its approaches in the autumn of 1969. It describes the main features of the incident, the investigations that were put in hand to ascertain the causes, and the conclusions that emerged.

2 The incident aroused public concern at the time and much speculation as to its cause. This is understandable. People are growing increasingly concerned about their environment and the far-reaching consequences that human interference with it can have. The sight of oiled birds on our beaches is unfortunately only too common these days; but depressing though it is, *at least the cause is obvious*. When beaches over a considerable area become scattered with unusually large numbers of dead or dying birds of which no more than fifteen per cent are oiled, and when the first sample to be analysed contains substantial residues of chemical substances (polychlorinated biphenyls) the biological effects of which are little known, it is right that the matter should be thoroughly investigated.

3 The Nature Conservancy acting in consultation with the voluntary bodies (paragraph 8) reported these facts to the Headquarters of the Natural Environment Research Council in the middle of October 1969, following a press statement by the Royal Society for the Protection of Birds. There followed an investigation involving some thirty organisations and laboratories working in collaboration with the voluntary societies. The work was planned and the results collated at two major meetings convened by the Secretary of NERC at Council Headquarters, one on 24 October and the other on 11 November.

4 The outcome as is reported in what follows, is that no single factor natural or artificial can be regarded with certainty as the main cause of the incident. There have been similar sea-bird wrecks in the past, before pollution can have been a possible cause. Widespread evidence of malnutrition was found among the dead birds in this incident but there was no evidence of shortage of the fish on which they feed: much more knowledge of the feeding habits of guillemots is however needed before these apparently contradictory facts can be reconciled. The effect of the malnutrition of the birds was probably compounded by natural causes including moulting, disease and gales (there were high winds during part of the period), and may have been aggravated by the toxic effects of the metallic and organic residues found in many of the dead birds. But no one of these factors can alone be regarded as the decisive cause of the incident.

5 It is quite possible that this is the true explanation of the mystery—ie that several different factors in combination were responsible. If so, the implications are not reassuring. It opens the possibility that although pollutants in the seas around Britain may not be present in sufficient concentrations to harm wild life directly, they may yet increase the chances that a bird or other organism which is under stress from some other cause will die rather than recover. Even a small shift in the balance between life and death could have a profound effect on the balance of whole populations.

6 A full account of this enquiry and the details of the laboratory work by the many Institutions (both within and outside NERC) which collaborated has been edited by Dr M W Holdgate who at the time was Deputy Director (Research) of the Nature Conservancy and who also acted as general co-ordinator during the incident. This account* is being made available in mimeograph to interested organisations in this and other countries which are concerned with pollution problems. Particular aspects will also be published in scientific journals by the investigators concerned.

* *The Seabird Wreck of 1969 in the Irish Sea: A Report of the investigation conducted under the auspices of the Natural Environment Research Council. Edited by Dr M W Holdgate.*

A

ORGANISATIONS PARTICIPATING IN THE INVESTIGATION

7 The Natural Environment Research Council (NERC), which acted as general co-ordinator for this investigation, has as its Prime function the scientific study and conservation of the natural environment and its resources. Research with this objective is promoted by the Council at a number of institutes and by grants to universities. That which is concerned with the investigation of the dynamics of wildlife populations must clearly take account of the possible effect of pollutants as well as of natural causes as factors influencing the stability of those populations.

8 Within NERC, the Nature Conservancy is Britain's official wildlife conservation body, but the country is fortunate in also having voluntary conservation organisations especially concerned with birds, notably the Royal Society for the Protection of Birds (RSPB), the British Trust for Ornithology (BTO) and the Seabird Group (a specialist group sponsored by the three major ornithological societies).* All these contributed to the investigation. In addition, officers of the Royal Society for the Prevention of Cruelty to Animals (RSPCA) and its Scottish counterpart, (SSPCA), members of local natural history societies and Trusts for Nature Conservation, and people from universities as well as private individuals helped in counting the casualties on the beaches and in collecting material for post-mortem examinations. The voluntary ornithological bodies also collected the records and prepared detailed casualty lists. Dr W R P Bourne of the Seabird Group collated and edited the evidence from all these sources.

9 Because the incident involved fish-eating sea birds while they were at sea, suspicion was at the time understandably directed towards the marine environment. For that reason the Fisheries Research Laboratories of both the Ministry of Agriculture, Fisheries and Food (MAFF) and the Department of Agriculture and Fisheries of Scotland (DAFS) were directly involved from the outset and played a major part in the investigations. Mr B B Parrish, Director of the DAFS Marine Laboratory, Aberdeen, co-ordinated the collection of samples of seawater and of marine life (including the small fish on which the birds feed).

10 On the laboratory side of the study, post-mortem examinations of the victims were carried out mainly by the Monks Wood Experimental Station of the Nature Conservancy and the Department of Animal Pathology of Cambridge University, and also by the MAFF Veterinary laboratories at Lasswade, the Central Veterinary Laboratory at Weybridge, the Laboratory of the Ministry of Agriculture of Northern Ireland in Belfast, and the Wildfowl Trust. Tests for the presence of viruses and bacteria were done by the Department of Animal Pathology at Cambridge, the Agricultural Research Council (ARC) Institute of Animal Diseases at Compton, the Medical Research Council (MRC) National Institute of Medical Research at Mill Hill, the MAFF laboratory at Lasswade and the Central Veterinary Laboratory at Weybridge. Chemical analyses were done by the Nature Conservancy at Monks Wood and at Merlewood Research Station in Lancashire, by five MAFF laboratories, by two DAFS stations, by CDE Porton and by the Laboratory of the Government Chemist: Monks Wood Experimental Station co-ordinated this work and collated the evidence from all these sources. A full list of all the organisations and laboratories involved, and the work they undertook is set out in Appendix I

THE 1969 INCIDENT AND COMPARISON WITH PREVIOUS WRECKS

11 The incident began with the arrival of small numbers of sick and dying birds on the shores of Northern Ireland early in September 1969. In the second half of September the mortality rate increased dramatically and many thousands of guillemots were cast up in North Wales, South-west Scotland, Northern Ireland and other areas around the Irish Sea. Strandings of smaller numbers of dead birds continued into November. Estimates, based on counts, indicate that over 12,000 dead birds came ashore. Oil pollution affected only a small proportion and where it did occur was almost all traced to local spillages. Ninety per cent of the mortality was among adult guillemots, mostly of the race breeding in the Southern areas of the British Isles. Most of them were in heavy moult at the time. The distribution of dead birds does not suggest that all the birds died from a single cause operating at one place and time.

12 Table 1 records the counts of dead birds on various coasts. It is clear that a dramatically large number of deaths occurred only around the Irish Sea and its approaches. The small numbers from the east and south coasts give an indication of 'normal mortality' at this time of the year and confirm that the number of deaths in the Irish Sea area was far higher than the norm.

* *The Royal Society for the Protection of Birds, the British Trust for Ornithology and the British Ornithologists' Union.*

13 The figures in Table 1 are subject to various errors. For instance the total number of birds stranded in south-west Scotland, where the greatest number came ashore, is derived from sample counts made on selected sections of beach to give an estimated figure for the whole coastline. The accuracy of the total of 17,347 dead birds depends largely on the accuracy of the estimate for guillemots found in SW Scotland, and to a lesser extent on similar estimates elsewhere. What can be said with certainty is that more than 12,000 dead birds probably came ashore round the Irish Sea in the three months from August to November, and the evidence of ringed birds, provided by the BTO, supports the view that the dead birds came mainly from colonies in the southern part of the Irish Sea. Because some are likely to have sunk or drifted into the open Atlantic, the total may well have been much higher; some ornithologists estimate the death toll as high as 50,000 100,000 birds.

14 Confronted with an incident of this kind, it is natural to search for precedents. Two species often involved in large scale wrecks in the British Isles, and indeed in the North Atlantic generally, are Leach's petrel (*Oceanodroma leucorrhoa*) and the little auk (*Plautus alle*). At least forty little auk wrecks have been recorded in the British Isles. They are often associated with storms, and a study of one of the most recent indicated that they result from a massed movement of birds from their normal Arctic habitat into more southerly waters deficient in food, where they become weakened and liable to be blown ashore by gales. The larger auks (puffin, guillemot and razorbill) are wrecked far less often than the little auk, and generally in smaller numbers. It is not unusual for a few tens or even hundreds to be cast ashore, but massed deaths like those of guillemots in the 1969 wreck are rare.

15 Previously recorded wrecks of large auks in the British Isles are summarised in Table 2 (page 4)

TABLE 1

Estimates and counts of dead birds on the beaches

(Most of these figures are based on the Beached Bird Survey organised by the RSPB and the Seabird Group)

SPECIES	EAST* SCOT-LAND	EAST ENG-LAND	SOUTH ENGLAND	WALES	NW ENGLAND	WEST SCOT-LAND	ISLE OF MAN	IRELAND	TOTAL	WINGS COL-LECTED	POST MOR-TEM
Observers	**10**	**24**	**23**	**67**	**22**	**49**	**6**	**21**	**222**	—	—
Divers and Grebes	1	4	—	1	3	—	—	—	9	—	—
Manx Shearwater	—	—	—	3	4	—	—	—	7	—	—
Fulmar	5	1	—	—	1	—	—	—	7	—	1
Gannet	6	3	3	7	5	3	3	5	35	—	—
Cormorant, Shag	2	1	1	4	6	3	2	—	19	1	1
Ducks	13	3	—	3	—	3	1	—	23	—	1
Waders	2	5	—	2	3	1	1	—	14	—	—
GBB Gull	6	3	—	—	6	—	2	—	17	—	—
Herring Gull	27	8	2	16	18	6	6	5	88	1	1
BH Gull	3	5	2	4	4	—	—	1	19	—	1
Kittiwake	5	7	1	2	4	1	3	2	25	—	2
Other Gulls	1	3	1	1	1	—	1	1	9	—	1
Terns	3	1	1	—	1	—	—	—	6	—	—
Razorbill	9	4	1	36	35	14	2	41	142	15	8
Guillemot	17	20	5	2019	898	11,816	320	1794	16,889	528	112
Other or unidentified Auks	2	1	—	30	1	3	—	1	38	—	—
TOTALS	**102ø**	**69ø**	**17ø**	**2128†**	**990ø**	**11,850†**	**341ø**	**1850†**	**17,347†**	**545**	**128**

*For boundaries of regions see map: page 8 †Guillemot figures partly based on estimates øBased on counts.

None of these wrecks closely parallels the events of 1969. The incident in 1859 was somewhat similar in that it occurred off south-west Scotland in late summer, just after the birds had left their breeding grounds. However, it is said to have killed mainly razorbills even though guillemots were abundant in the area. The total death roll was probably less than in 1969 although the auk populations are believed to have been many times larger a century ago. The wreck in 1889 is very poorly documented but also seems to have happened just after the breeding season and may have coincided with severe gales. The symptoms of the birds that died in the highly local wreck in the Solway in 1907 seem reminiscent of those in 1969, and the timing is similar, as it was in 1941.

16 It seems clear, therefore, that there have previously been wrecks of the larger auks in the period August-September. These have often coincided

TABLE 2

Wrecks of the larger auks in British waters

DATE	PLACE	MAIN SPECIES	OTHER SPECIES	MORTALITY	OTHER OBSERVATIONS
1856 (11 May)	North Norfolk	guillemot	razorbill, puffin, gulls	'large numbers' (240 counted in 2 miles)	Severe north-westerly gales in early May. Remarkable as no auks breed in the vicinity.
1858 (September)	North Norfolk	guillemot	puffin, razorbill, scoter, divers	'large numbers'	
1858 (date uncertain)	Cornwall	puffin	not stated	'large numbers'	
1859 (about August)	Western Scotland (Clyde to Belfast Lough)	razorbill (90%)	guillemot, puffin, gulls	'hundreds, even thousands'	Severe storms noted elsewhere at the same period.
1867	Outer Hebrides	all auks		'a great number'	Bad weather during breeding season caused many to die on the ledges.
1872 (early in year)	England and Scotland	razorbill	none (noted at time)	'Many'	
ca. 1889 (late summer)	Ailsa Craig	larger auks		'massive' (many thousands?)	Deaths after leaving breeding places said to have greatly reduced population.
1895 (August-September)	Loch Leven (Argyll)	guillemot, razorbill		not stated	Some birds blown inland by gales.
1907 (August-September	Solway Firth	guillemot	razorbill	heavy and prolonged	Young and old guillemots: some razorbills. Came close inshore or stranded in helpless condition. In good plumage but emaciated with empty stomachs.
1911-1913	Ailsa Craig, Rathlin Island, St. Kilda	guillemot, razorbill	puffin, kittiwake	progressive decline in breeding populations	Gannets on Ailsa Craig unaffected as were seabirds generally in Shetland, Orkney and east coast.
1941 (September)	Firth of Clyde	guillemot	not recorded	about 2,000	

with stormy weather, which may have been the primary cause in some cases but in others may have driven ashore or despatched birds that had already been weakened by other factors such as disease or malnutrition. The larger auks, both adults and young, are flightless (in moult or with growing feathers) and at sea during this period.

THE INVESTIGATION

17 The first step was to review what was happening at the time in the natural environment; the weather, the sea currents, the state of marine life, and especially the abundance of the fish on which the birds feed—both at the time of the incident and in the months leading up to it. If the deaths were due to purely natural causes, there ought to be evidence of something else amiss in the Irish Sea during this period.

18 Although the main strandings of the dead and dying birds coincided with the stormy weather in the last weeks of September, over a hundred came ashore before the onset of the storms. This suggests that many birds were already weak or dying before the gales began. The storms may have increased the stress on the birds and raised the mortality, besides bringing many more victims to the beach, but they appear to have been a secondary rather than a prime or the sole cause of the deaths. A contributory factor could have been the moulting of the birds as already indicated (paragraph 16).

19 An examination of the abundance and distribution of the fish species on which the birds normally depend for food was undertaken, and a search made for evidence of 'blooms' of phytoplankton or toxic algae which might be poisonous to guillemots. No evidence of a food shortage or of an abnormal abundance of toxic algae was found. But we know too little of the detailed feeding behaviour of the birds, or of the particular combinations of weather and sea conditions which affect the birds' feeding success, for these negative results to be conclusive.

20 **The condition of the birds**—Bird wrecks in the past have been attributed to disease and some of the features of the 1969 incident suggested that an epidemic of some kind might have occurred. These features included the apparent sickness of the birds observed before the main peak of deaths, the lack of precise conformity between the pattern of deaths and the pattern of storms, and the way in which the number of deaths built up and then died away. Tissues from some 46 guillemots and one razorbill, common gull, herring gull and kittiwake that died in the disaster, and from one apparently healthy guillemot that was shot, were therefore submitted to microbiological examination, but tests for pathogenic viruses and bacteria proved negative in all cases. Disease cannot however, be wholly eliminated as a cause of the disaster because of the time that unavoidably elapsed between the deaths of many of the birds and their arrival at the laboratories, but the tests provide no evidence for this as a cause of death.

21 Post mortem examinations were carried out on 129 seabirds (112 being guillemots) and one mute swan; and as healthy specimens were needed for comparison, 18 guillemots were shot late in the autumn. All the laboratories agreed that the auks that died in the incident were in a poor state of nutrition. Their fore guts and muscular stomachs were empty, in contrast to those of the shot birds which contained either fish or the residues of a recent meal. Almost all the bodies felt very light and thin, with prominent breastbones; in a sample of sixty-one the average weight of the birds was between half and two thirds that of apparently healthy birds. The dead birds lacked subcutaneous fat, and most had wasted breast and thigh muscles. More unusual and perhaps more significant were changes found in the livers and kidneys of the birds that died in the incident. All the livers were dark and full of blood, and detailed microscopic investigation of five of them showed unusual changes in the tissues. The kidneys of most of the casualties appeared swollen and unusually pale in colour, and superficially resembled those of Bengalese finches killed by PCB poisoning in an experiment at Monks Wood.

22 The different laboratories did not entirely agree in the interpretation they put upon their post mortem findings, although much of the divergence of view was probably due to the small number of samples that it was practicable to examine in many cases, the partly-decomposed state of much of the material, and the paucity of knowledge of the normal internal condition of healthy birds. The Monks Wood and Cambridge laboratories, which between them examined the great majority of the specimens, noted that pathological changes were present in the majority of the birds examined, but that there was no evidence of specific disease or of oil poisoning. They also concluded that in no case could death be attributed directly to starvation. However, a poor to very poor state of nutrition was characteristic of all their sample of birds, and they concluded that they had not fed adequately for some time and had been drawing heavily upon their body reserves.

23 The specialists at the Central Veterinary Laboratories, who were able to carry out histological examinations of material from a limited number of birds, reported that there was a consistent pattern in the unusual histological changes in the liver. It was considered that the most likely cause of the lesions in the liver was a poison of some kind. This toxin could have been absorbed from the intestines and carried by the blood to the liver and kidneys, where it may have had a specific toxic effect on the veins and tissues around them. The hepatic lesion was thought to be striking and unusual, and it may be significant that similar symptoms have been observed in chicks fed with PCB in an experiment.

24 The workers at the Compton laboratory, in contrast, noted no macroscopic lesions in any of their birds, and reported that there were no signs of obvious disease. They concluded that the deaths were due to starvation.

25 The programme of analysis—A large part of the effort of the laboratories who collaborated in investigating the 1969 seabird wreck was devoted to chemical analyses. Samples of sea-water, and marine life of all kinds as well as the tissues of the seabirds themselves were analysed for toxic substances. The reader who is interested in the results of these analyses will find them in Appendices II to IX at the end of this report, and only a short account of the work is given below. A complete account of the laboratory methods and results is provided in the full report and supplement already referred to in the Introduction. Caution is needed in interpreting the data as the number of specimens it was possible to examine was small in relation to the total seabird mortality and indeed smaller than is statistically desirable.

26 Metallic residues—Traces of many metallic elements are naturally present in animal tissues but are toxic in excess. Analyses for four metals in sea-water and marine life are given in Appendix II. A comparison with the figures shown there for samples from other areas indicate that the Irish Sea and its marine life do not appear to carry higher concentrations of these metals than the other coastal regions of Britain which have so far been examined. Appendix III shows the concentrations of various metals found in the livers and kidneys of guillemots. Some of the dead birds showed relatively high levels of particular metals and in some cases the highest concentrations were above the level at which poisoning may have occurred. In general the range in the casualties of the incident and in healthy birds shot for comparison overlap.

27 These analyses were of course undertaken before the presence of mercury residues in imported tinned tuna fish attracted publicity in the autumn of 1970. The levels of mercury, lead, cadmium and arsenic in the livers and kidneys of some birds are unquestionably high, although they may have been elevated by shrinkage of the organs after death and they should not be taken as precise indicators of the situation in the general seabird population. Nevertheless such observations of high tissue concentrations in predators should alert us to the possibility of hazardous levels of these potentially toxic substances in British inshore waters. All these metals are in fact natural components of sea water in minute amounts, and more research is needed to indicate whether these background levels have been raised to significant amounts by pollution.

28 Organic insecticides and PCBs—Some of the first analyses of dead birds carried out at Monks Wood Experimental Station confirmed the presence of residues of the organochlorine pesticides DDE (a breakdown product of DDT) and dieldrin and suggested also that unusually high concentrations of polychlorinated biphenyls (PCBs) were present in the livers. An extensive programme of analyses for the organochlorines and PCBs in sea-water, marine life and sea birds was therefore carried out. The results are given in Appendices IV to IX.

29 The organochlorine pesticides may have considerable effects on living tissues, but their 'background level' in the environment is normally well below that likely to harm wildlife. However, their solubility in fat causes them to be accumulated in the fatty tissues of animals. Aquatic plants and small marine organisms contain only minute amounts of these compounds, but their concentrations increase as they pass up the food chain to predators such as fish or birds. Seabirds as long-lived animals, coming at the end of such a food chain, can acquire large quantities of organochlorines even when these are present in the environment at very low concentrations. When such birds come under stress, or suffer from shortage of food, they draw on their reserves of body fat and so mobilise accumulated residues, which pass into the bloodstream and so reach, and may affect, important organs. Birds containing significant amounts of organochlorine pesticides, even when not otherwise stressed are known to suffer disturbances of their calcium carbonate metabolism and behaviour, lay thin-shelled eggs, and have a lower breeding success than normal.

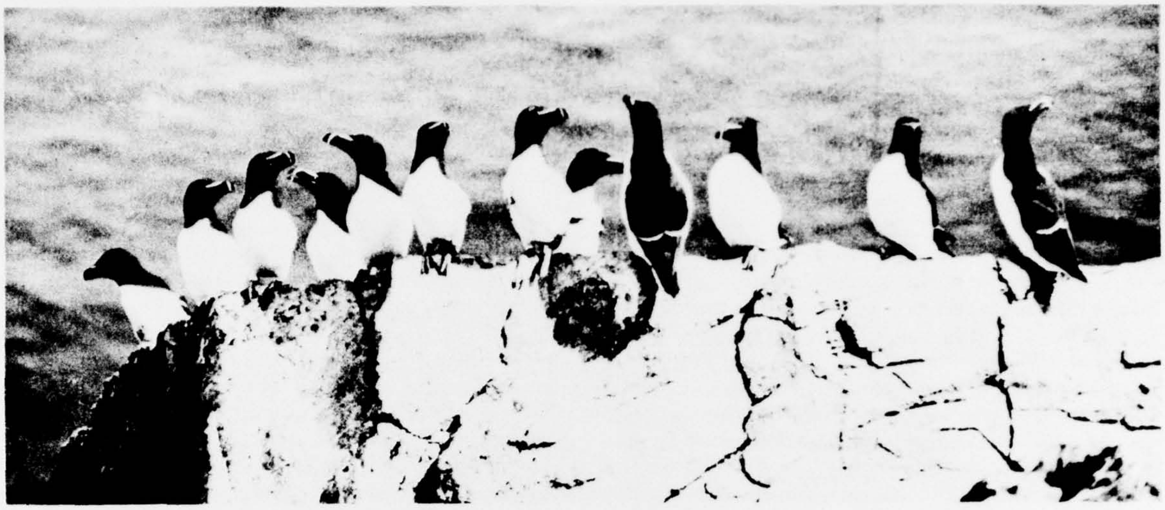
30 PCBs are not pesticides. In this country they have a wide variety of uses in industry. They are, however, organic compounds containing chlorine, have the same properties of persistence, fat solubility and biological activity as DDT and dieldrin, and can be concentrated in food chains. Their effects on birds are less well known than those of organochlorine pesticides, but preliminary experiments indicate that they can have similar effects although they appear to be somewhat less toxic to birds than DDT.

31 The concentrations of PCBs and organochlorine pesticide residues in sea water, invertebrate marine life and fish from the general area of the bird-kill were not unusually high and were generally within the range observed previously in this area and elsewhere. The concentrations of DDT and dieldrin in fish were mostly lower than those of PCBs. The results are set out in Appendices IV and V.

32 The quantities and significance of organochlorine pesticide residues in British wild birds have been studied for nearly ten years by a number of laboratories and especially at the Nature Conservancy's Monks Wood Experimental Station, so that there is a good basis for comparison. Particular attention has been paid to the concentrations found in the livers and eggs of birds of prey and freshwater fish-eaters such as the heron. Since 1966, most specimens have been tested for PCBs as well as for organochlorine pesticides. Sixty birds that died in the present incident were examined for PCB residues by Monks Wood and three other laboratories and ten apparently healthy guillemots were shot for comparative study. Most of the dead birds analysed were guillemots, the remainder comprising razorbills, a mute swan, shag, black headed gull and Kittiwake. The results are given in Appendices VI and VII. The number of samples is too small to provide a meaningful analysis of regional variation in PCB levels in the area of the wreck, but the wide range of variation in the results for all areas is noteworthy. The levels in the small sample of razorbills appear somewhat lower than in the guillemots, but there are too few analyses, and too great a variation, for this to be regarded as significant.

33 In Appendix VIII a comparison is made between two small samples of five shot birds (guillemots) and five which died in the wreck as regards the concentrations of PCB and organochlorines found in the liver and the rest of the body. In Appendix IX, which is computed from Appendix VIII, the total body contents of these residues are compared for the shot birds and those that died in the wreck. Although the sample is very small, it is clear that the total body loads of PCB and pesticide residues were broadly similar in healthy birds and those that died in the wreck, and that the higher concentrations found in the livers of the dead birds are likely to have resulted from a redistribution of residues between the organs of the victims, rather than from a generally higher level of contamination.

Maximum counts of dead Auks, Sept.-Nov. 1969



CONCLUSIONS

34 One of the most striking findings of the analytical programme was the presence in the livers of most of the dead guillemots of unusually high levels of PCBs. In contrast to the situation previously recorded in British land and freshwater birds, these levels were higher than those of residues of the organochlorine insecticides DDT and dieldrin. A study of the occurrence of these substances in the sea and in marine life confirmed that the birds could readily have obtained them from their normal food, and accumulated them initially in their body fat. There was no evidence that marine life in the Irish Sea area contained more PCBs than similar organisms elsewhere in British waters, or that there had been a sudden rise in PCB levels during the summer of 1969. Analysis showed that the *total* amount of PCBs, DDE and dieldrin in the bodies of an admittedly small sample of apparently healthy seabirds shot outside the area of the incident were as great or greater than those in the victims of the bird kill. The latter were peculiar only in the high concentration of residues in their livers.

35 These findings are meaningful when it is remembered that PCBs and DDE are soluble in fat and within an animal tend to accumulate in the body fat reserves, where their toxicity is of little significance. The seabird victims of the disaster had no body or liver fat: all the PCBs and other organochlorine residues they contained must therefore have been mobilised with the fat and passed to the liver, kidney, brain and other tissues.

36 It may be asked whether this mobilised PCB could have caused the damage to the liver and kidney tissues recorded in the post-mortem examinations, and whether this damage was in itself severe enough to have been the direct cause of death. The similarity between some of the tissue changes in the dead birds and those produced in Bengalese finches, chickens and quails fed with PCBs under experimental conditions certainly supports the hypothesis that the observed tissue concentrations could have had this effect.

37 The significance attached to the observed lesions varied, however between the laboratories that examined them. Consistent interpretation was hampered by the lack of information about the anatomy of healthy birds and of those that have died of starvation in the absence of poisoning of any kind. More research is needed, especially on the behaviour of PCBs when fat is mobilised under conditions of stress, and on the fate of PCBs in tissues after death.

38 If PCB poisoning had been the primary cause of death one would expect that the PCB levels in the birds that died would have been greater than in the birds that survived. In practice this would not appear to have been the case, for the sample of 5 apparently healthy birds shot after the incident contained similar amounts of PCB as five randomly-selected birds that died in the incident. On that evidence it seems that, whatever the effect PCBs may or may not have had once they were mobilised, they could scarcely have been the initial cause of the mortality. Concentration of PCB in the liver and kidney could have occurred only *after* the fat reserves had been mobilised—that is, after the birds had been seriously affected by malnutrition. The difficulty with this hypothesis is that there appears to have been no shortage of food for the birds in the affected areas at the time of the incident, but again we are lacking the critical information. The relationship between birds and their food is a subtle one and very little is known about it.

39 We can summarise the story of this incident by saying that although the seabird wreck does not seem to have originated at one point in space or time, there is evidence to suggest that most birds died in a broad belt of water along the east coast of Ireland at a time when the adults were in moult and therefore vulnerable to additional stress. The wide distribution of dead birds, even after allowing for the effect of wind and tidal movements, does not support the hypothesis that birds died as a result of contact with a toxic substance at one, or a few, point sources. Storms certainly brought the main wave of dead and dying birds ashore, but some strandings preceded the bad weather, suggesting it was not the sole cause. Low body weight and malnutrition were more in evidence than any particular pathological condition, and history shows that sea-bird wrecks have occurred from natural causes before pollution could have been a factor. The relatively high values of PCBs in the livers of some dead birds probably arose because they had mobilised their body fat reserves during a period of malnutrition or interrupted feeding. This could have added to the stress imposed by storms, moulting and starvation, account for the pathological signs found in liver and kidneys, and may have loaded the odds against recovery.

40 In closing we should return to the point made in the Introduction to this report, namely that even if pollutants in the seas around our coasts are not yet sufficiently concentrated to harm wildlife by themselves, they may on occasions tip the scale between life and death, and the effect of this precarious situation could be to affect the balance of whole populations. There is as yet no proof that this is happening but the possibility cannot be ignored. It would clearly be impracticable to mobilise resources on the scale they were on this occasion every time there was a hint of trouble (and many reports turn out to be exaggerated or false) as it would lead to a massive waste of money and of the time of skilled people. The solution is a continuous monitoring of selected components of the environment (of which wildlife populations are one) likely to be the most sensitive 'indicators' of pollution hazards. This involves, particularly, a better understanding of the biological significance of pollutants to which the natural fauna and flora are exposed. NERC, together with the other Research Councils, Departments of Government, universities and the voluntary conservation bodies are taking steps to meet this problem.

APPENDIX I.

Participating Departments and Laboratories

DEPARTMENT	ORGANISATION	LABORATORY OR SECTION	WORK UNDERTAKEN
Education and Science	Natural Environment Research Council (NERC)	Headquarters	General co-ordination, liaison with Departments.
	NERC: Nature Conservancy	Headquarters	Co-ordination of work of regional and research staff: liaison with voluntary ornithological bodies.
	NERC: Nature Conservancy	Monks Wood Experimental Station	Co-ordination of collection and distribution of seabird material for study: post mortems and analyses for PCBs and organochlorine pesticide residues. Collation, interpretation and analysis of results.
	NERC: Nature Conservancy	Merlewood Research Station	Analyses of organs for metals etc.
	NERC: (aided institution) Scottish Marine Biological Association (SMBA)	Oban (Dunstaffnage) Laboratory	Collection of dead birds, water and plankton samples.
		Oceanographic Laboratory, Edinburgh	Records of plankton.
	NERC (Research Unit) at University College of North Wales	Unit of Marine Invertebrate Biology, Bangor	Counts and collection of birds: studies of bird drift: observations on status of marine invertebrates: collection of fish, plankton and water samples.
	Agricultural Research Council (ARC)	Institute for Research on Animal Diseases, Compton	Post-mortem studies of birds: pathology
	Medical Research Council (MRC)	National Institute of Medical Research, Mill Hill	Post-mortem studies of birds: virology.
Ministry of Agriculture Fisheries and Food (MAFF)		Fisheries Laboratory, Lowestoft	Oceanographical data: collation of marine information.
		Radiobiology Laboratory, Lowestoft	Measurement of radioactivity levels in bird tissue.
		Fisheries Laboratory, Burnham on Crouch	Analyses of water, plankton, invertebrates and fish.
		Veterinary Laboratory, Lasswade	Post mortem examination of birds: virology and bacteriology.
		Central Veterinary Laboratory, Weybridge	Post mortem examination of birds.
		Pest Infestation Control Laboratory Tolworth	Analyses of bird tissue for organophosphorus PCBs and organochlorine pesticide residues.

APPENDIX 1 (continued)

DEPARTMENT	ORGANISATION	LABORATORY OR SECTION	WORK UNDERTAKEN
Department of Agriculture and Fisheries for Scotland (DAFS)		Marine Laboratory Aberdeen	Overall co-ordination of marine studies. Collection of data on plankton, fish.
		Freshwater Fisheries Laboratory, Pitlochry	Analyses of water, invertebrates, fish and 1 bird.
Ministry of Agriculture, Northern Ireland		Veterinary Research Laboratory, Belfast	Post mortem examination of birds: Analyses for metals, cyanide, organophosphorus etc.
Ministry of Technology (now, Department of Trade and Industry)		Laboratory of the Government Chemist	Analyses of bird tissues for PCBs and organochlorine pesticide compounds.
Ministry of Defence		Chemical Defence Experimental Establishment Microbiological Research Establishment, Porton Down	Post mortem examinations of birds, chemical analyses and serological and bacteriological investigations.
Ministry of Development Northern Ireland		Amenity Lands Branch	Collection and counting of dead birds.
Non-Governmental	University of *Cambridge*	Department of *Animal Pathology*	Post-mortem examination of birds: bacteriology, virology.
	University of Liverpool	Marine Biological Station, Port Erin, Isle of Man	Collection of fish, plankton and water samples: counts and observations of birds.
	Royal Society for the Prevention of Cruelty to Animals		Collection and counting of dead birds.
	Scottish Society for the Prevention of Cruelty to Animals		Collection and counting of dead birds.
	Royal Society for the Protection of Birds		Collection and counting of dead birds, collection of data on birds found dead.
	British Trust for Ornithology		Interpretation of ringing returns.
	Seabird Group		Collation and interpretation of records of bird deaths.
	Beached Birds Survey (Organised by RSPB and Seabird Group)		First produced data about the incident, and much of the information in Table 1 (see paragraphs 12, 13)
	Wildfowl Trust		Post-mortem of dead birds.

APPENDIX II

Concentrations of metal in sea water and marine life
Mean and (range). n = number of samples

SAMPLE	ELEMENT				UNITS
	Cu	Pb	Zn	Cd	
Sea water, Cardigan Bay	2·0* (0·9—6·0)	3·6* (2·3—4·9)	12·0* (6·4—21·7)	1·3* (0·6–3·0)	Micrograms/ Kilogram or litre
Sea water, Conway Estuary	3·0 (n = 1)	3·6 (n = 1)	8·8 (n = 1)	0·76 (n = 1)	
Sea water, Other seas	(1—20)†	(3·5—8)ϕ	(0·06—33)†	(0·02—0·17)†	
Bodies of seven species of crustacea (Irish Sea)	36·0 (n = 7) (1·2—240)	2·6 (n = 7) (0·38—13)	72 (n = 7) (53—99)	1·6 (n = 7) (0·48—4·6)	
Bodies of two species of crustacea (English south and east coasts)	(55—100) (n = 26)ϕϕ	(5—15) (n = 26)ϕϕ	(55—200) (n = 26)ϕϕ	—	Parts per million (ppm) dry weight
Bodies of twelve species of mollusc (Irish Sea)	60 (n = 12) (3–270)	12·7 (n = 12) (0·76—42)	345 (n = 12) (84—940)	12·3 (n = 12) (1·2—73)	
Bodies of four species of mollusc (English south and east coasts)	(10—4000) (n = 30)ϕϕϕ	(10—50) (n = 30)ϕϕϕ	(10—10,000) (n = 30)ϕϕϕ	— —	
Bodies of four species of fish (Irish Sea)	(6·2—10) (n = 4)	(0—5·8) (n = 4)	(62·110) (n = 4)	(0—1·5) (n = 4)	
Mackerel, (Irish Sea)	(7·5—10) (n = 10)	5·0 (n = 10)	(25—60) (n = 10)	—	
Cod, (North Sea)	(5—8·5) (n = 20)	5·0 (n = 20)	(11—18) (n = 20)	— —	Parts per million (ppm) dry weight
Whiting, (North Sea)	(5—17·5) (n = 20)	5·0 (n = 20)	(13—34) (n = 20)	—	
Mackerel (English Channel)	(5—12·5) (n = 20)	(2·5—12·5) (n = 20)	(26·5—60) (n = 20)	— —	

* Mean figures of measurements made at twelve sites round Cardigan Bay.

† Riley & Skirrow., Chemical Oceanography (1965). *Range quoted taken from a large number of* determinations over a period.

ϕ Riley & Skirrow (1965). Figures obtained in 1938 and now considered to be over-estimates.

ϕϕ The 26 samples in this case comprised 16 lobsters and 10 samples of shrimps.

ϕϕϕ The samples in each case included 5 or 6 individuals.

Note that in the third section, the sample numbers represent the number of fish analysed.

APPENDIX III

Element Concentrations in Sea Bird Tissues
(bracketed figures are numbers of samples analysed)

SAMPLE (LABORATORY)	Pb	As	Hg	Sb	Zn	Cu	Cd	Ni
	ELEMENT CONCENTRATIONS IN MICROGRAMS/GRAM DRY (M) OR WET (B) WEIGHT							
Dead guillemots (Merlewood)								
liver (M)	0·8—>40 (22)	<0·1—38 (21)	<0·1—23 (21)	<0·2—410 (21)	11—600 (21)	<1—100 (22)	0·2—13 (21)	0·42—0·84 (4)
kidney (M)	2·4—>40 (11)	<0·1—8·9 (14)	<0·1—7·2 (14)	<0·2—82 (13)	76—1000 (12)	26–76 (14)	1 0—12 (12)	—
Shot guillemots (Merlewood)								
liver (M)	0·2—2·6 (7)	0·7—20 (7)	0·11—2 (7)	0·2—7 (7)	48—98 (7)	1·9—25 (7)	0·1—1·3 (7)	0·34—0·75 (4)
kidney (M)	1·7 (1)	<0·1 (1)	<0·1 (1)	16 (1)	72 (1)	<1 (1)	0·2 (1)	—
Dead guillemots (Belfast)								
liver (B)	0—5·0 (6)	0—9·0 (10)	—	—	—	—	—	—
kidney (B)	0—5·0 (6)	0·2—1·4 (4)	—	—	—	—	—	—
Shot guillemots (Belfast)								
liver (B)	0 (2)	0·7—1·4 (2)	—	—	—	—	—	—
kidney (B)	0—2·0 (2)	0·2—0·3 (2)	—	—	—	—	—	—

Wet weight data (B) may be converted to dry weight (M) by multiplying by 4·6.

APPENDIX IV

Estimated concentrations of organochlorine residues in sea water and invertebrate marine life

SAMPLE	LOCALITY AND DATE	NUMBER OF SAMPLES ANALYSED	CONCENTRATIONS: MICROGRAMS/LITRE OR KILOGRAM PCB	DIELDRIN & TOTAL DDT
Sea water	Irish Sea 23-30 Oct 69 Firth of Clyde 1 Dec 69	53	<0·01	<0·001—0·005
Zooplankton	S E Isle of Man Oct 69 Clyde Oct 69 South Minch Oct 69	7	<10—30	<10
Mussels (whole, less shell)	Clyde Oct 66	2 (10 specimens)	200—800	100—300
	Scottish coast Oct 66	7 (70 specimens)	<100—300	60—100
	English E coast Feb 68	14 (10 specimens)	10—200	20—140
	Irish Sea Oct 69	17 (8-16 specimens)	50—100	<10
Shrimps	Thames Estuary Spring 69	12 (25 specimens)	10—200	20—140
Norway lobster	Irish Sea Oct 69 Clyde Oct 69 W Coast Scotland Oct 69	3 (11 specimens)	<10—100	10—100

APPENDIX V

Range of concentrations of organochlorine residues in fish tissues
(bracketed figures are numbers of samples and total numbers of individuals sampled)

SAMPLE		LOCALITY AND PERIOD	CONCENTRATIONS IN MICROGRAMS/KILOGRAM WET WEIGHT PCB		DIELDRIN & TOTAL DDT	
Herring	Muscle	Irish Sea—Clyde before Oct 69	10— 1,500	(4:32)	10— 900	(4:32)
		Other areas before Oct 69	100— 5,000	(8:64	90— 300	(8:64)
	Liver	Irish Sea—Clyde before Oct 69	<100— 2,600	(3:22)	10— 800	(4:32)
		Other areas before Oct 69	10— 100	(1:1)	100— 300	(5:41)
Herring	Muscle	Irish Sea—during and after Oct 69	<10— 2,600	(3:30)	150— 300	(2:20)
		Other areas—during and after Oct 69	20— 200	(10:114)	10— 300	(10:114)
	Liver	Irish Sea—during and after Oct 69	10— 2,000	(3:30)	20— 300	(2:20)
		Other areas—during and after Oct 69	10— 1,900	(7:70)	10— 400	(7:70)
	Whole Fish	Irish Sea—during and after Oct 69	10— 2,000	(3:154)	10— 1,000	(3:154)
Whiting	Muscle	Irish Sea—before Oct 69	10— 600	(7:45)	10— 140	(7:45)
		Other areas—before Oct 69	10	(11:55)	10	(11:55)
	Liver	Irish Sea—before Oct 69	100—27,000	(7:45)	130— 5,000	(5:25)
		Other areas—before Oct 69	100— 5,000	(11:55)	300— 3,000	(11:55)
Whiting	Muscle	Irish Sea—during and after Oct 69	10— 400	(3:18)	10	(1:5)
	Liver	Irish Sea—during and after Oct 69	1,000— 7,000	(2:15)	1,000— 2,000	(1:5)
Cod	Muscle	Irish Sea—before Oct 69	300— 1,800	(1:5)	400— 520	(1:5)
	Liver	Irish Sea—before Oct 69	4,500—50,000	(1:5)	2,300—12,400	(1:5)
Other fish*	Muscle	Irish Sea—during and after Oct 69	<5— 400	(6:44)	10 100	(6:44)
	Liver	Irish Sea—during and after Oct 69	150— 6,000	(5:41)	30— 2,000	(3:18)
	Whole fish	Irish Sea—during and after Oct 69	100— 1,000	(3:83)	40— 1,000	(3:53)

*Includes sprat, sandeel, whiting, mackerel, long rough dab and grey mullet.

APPENDIX VI

Concentrations of organochlorine residues in guillemot livers
n = number of birds examined, mean, number of samples and (range) given

LOCALITY, TIME OF COLLECTION, AND NUMBER OF BIRDS EXAMINED			ESTIMATED ORGANOCHLORINE CONCENTRATIONS IN MICROGRAMS/KILOGRAM WET WEIGHT PCB	DDE	DIELDRIN
Argyll	28/9—21/10	n = 3	<2,000 (3 samples)	—	—
Clyde	1/10—23/10	n = 19	129,000 (8,000—880,000) (19 samples)	9,900 (1,700—17,000) (11 samples)	—
North-East Ireland	14/10—29/10	n = 5	14,000 (8,000—20,000) (5 samples)	6,400 (2,300—11,000) (5 samples)	250 (200—300) (4 samples)
Eastern Irish Sea	23/10—3/11	n = 7	161,000 (80,000—230,000) (7 samples)	22,000 (20,000—25,000) (2 samples)	250 (trace—500) (2 samples)
North-west Wales	7/10—22/11	n = 13	87,000 (6,000—300,000) (13 samples)	10,000 (4,500—19,000) (7 samples)	500 (300—800) (4 samples)
South Wales	25/10	n = 2	325,000 (260,000—390,000) (2 samples)	—	—
Overall average	28/9—22/11	n = 49	111,000 (2,000—880,000) (49 samples)	10,200 (1,700—25,000) (25 samples)	400 (trace—800) (10 samples)

APPENDIX VII

Estimated levels of organochlorine pesticide residues and PCBs in livers of seabirds.

SPECIES	LOCALITY	DATE FOUND	ESTIMATED LEVELS OF ORGANOCHLORINES (IN PPM) PCB	DDE	HEOD (DIELDRIN)
Razorbill	Cumberland	12.11.69	20	12	<1
Razorbill	Cumberland	12.11.69	44	9	<1
Razorbill	Cumberland	13.11.69	16	5	<1
Razorbill	Cumberland	14.11.69	40	10	<1
Razorbill	Cumberland	14.11.69	10	6	<1
Razorbill	Anglesey	25.10.69	<2	—	—
Razorbill	Pembroke	4.11.69	12	4	<1
Mute Swan	Anglesey	25.10.69	<2	—	—
Kittiwake	Co. Down	28.10.69	10	0·4	0·1
Black-headed Gull	Cheshire	1.11.69	6	0·5	1·1
Shag	Co. Down	28.10.69	0	0·1	0·1

Where a dash appears, substance concerned was not looked for.
Multiply figures by 1,000 to give micrograms per kilogram.

APPENDIX VIII

Concentration of organochlorine residues in tissues and whole birds (guillemots).

	SAMPLE	CONCENTRATION IN PPM (WET WEIGHT) (EACH FIGURE IS THE ARITHMETIC MEAN OF FIVE RESULTS—RANGE IN BRACKETS) PCB	DDE	DIELDRIN
Shot birds	Liver	0·4 (2—0)	0·24 (0·4—0·1)	0·16 (0·4—trace)
	Rest of body	3·4 (7—1)	1·46 (3·1—0·6)	0·54 (1·0—0·2)
Birds found dead	Liver	56 (200—10)	10·80 (25—4·5)	0·54 (0·8—0·3)
	Rest of body	3·2 (10—1)	0·92 (2—0·4)	0·10 (0·4—trace)

APPENDIX IX

Estimated total body content of PCBs and organochlorine pesticide residues in guillemots found dead and in apparently healthy birds. Computed from data in Appendix VIII

	ESTIMATED TOTAL BODY CONTENT (MICROGRAMS) MEANS AND (RANGES) PCB	DDE	DIELDRIN
Guillemots found dead	2,700 (800—8900)	673 (314—1535)	62 (6—232)
Guillemots shot	3,500 (800—7,200)	1,484 (468—3,211)	545 (155—990)

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