COOPERATIVE RESEARCH REPORT

No. 121

REPORT ON THE MEETING OF AN AD HOC WORKING GROUP ON ASSESSMENT
OF HARP AND HOODED SEALS IN THE NORTHWEST ATLANTIC

ICES Headquarters, 4-7 October 1982

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1. ORIGIN AND TERMS OF REFERENCE

The Working Group was convened in response to a request by the Government of Canada and the EEC Commission for scientific advice from ICES on aspects of the population dynamics and state of the harp and hooded seal stocks in the Northwest Atlantic, with particular reference to:

"1. Current stock size and pup production, and recent trends in these parameters.

2. Replacement yield and sustainable yield at present stock size and in the long term, under varying options of age compositions in the catch, including that which has recently prevailed.

3. Foreseeable trends in population size based upon different levels of total allowable catch incorporating quota regulation of all removals except that by traditional hunting in the Canadian Arctic and in Greenland.

4. The effects of recent changes in the food supply available to harp seals on the current status of the stocks and on the predictability of future population trends.

5. The confidence limits to the above-mentioned estimates."

The Working Group, comprising scientists from Canada, Denmark, Federal Republic of Germany, Netherlands, Norway, United Kingdom and USA met at ICES headquarters from 4-7 October 1982. A list of the participants is given in Appendix I.

In pursuing its main task, as set out in the above terms of reference, the Working Group reviewed the relevant scientific information on harp and hooded seals contained in published papers and other documents including those presented in recent years to meetings of ICNAF/NAFO scientific committees. In addition, new information was given in documents presented at the present meeting, a list of which is given in Appendix II. No new assessments were made at this meeting. All estimates apply to the Northwest Atlantic only, and do not refer to any other harp or hooded seal stock.

The Working Group points out that estimates of abundance presented at this meeting were scrutinized in terms of their reliability and robustness under possible violations of assumptions as well as sampling error. This robustness was taken into account in formulating the Working Group's advice. The methodological discussions are summarized below, followed by the Working Group's consideration of the specific items on which ICES advice had been sought.

Precise definitions of technical terms are provided in the Glossary (Appendix III).

2. METHODS

Four main groups of assessment techniques have been used in the past and were also available at the meeting. The first two rely heavily on catches at age and are:-

(i) calculations of a pup production independent of assumptions about the magnitude of the natural mortality rate (M);

(ii)   calculations of pup production levels over time, or of a single pup production level and M;

The two other groups are:-

(iii)   mark and recapture analyses;

(iv)   direct census techniques, such as aerial surveys.

2.1   Estimation of Pup Production Independent of Natural Mortality

The original Survival Index method (see Appendix III) has often provided a basis for past assessments (eg Winters, 1978). However, various workers have criticized the method and alternatives have been suggested. Note was made of the extensive list of assumptions on which the Survival Index is premised (see Goodman - this meeting).

Goodman presented a paper which showed that, even if the assumptions of the Survival Index method were met, estimates from it would theoretically contain an upward bias owing to underlying non-linearity in the relationship. This is consistent with the simulation studies of Beddington and Williams (1980). As an illustration, a particular non-linear functional form was substituted in the fitting procedure. This gave a lower estimate of pup production than the linear form. The intention of the argument, however, was to recommend the abandonment of Survival Index calculations in the future rather than to suggest further attempts at correction or modification. During the Working Group's discussions strategies of analysis which did not suffer from the bias of the Survival Index, and which required less stringent assumptions, were put forward (Cooke, Jacobsen, Ugland - this meeting).

Goodman also provided sample calculations of population size and population projections under various assumptions, purely for example. Estimates of current pup production for hooded seals required projections from the estimates for the mid-1960's. Even a modest uncertainty about these estimates would compound into a large uncertainty about the present value of pup production.

A paper by Cooke (this meeting) described two further methods for estimating pup production from catch at age data. The methods utilize the basic idea of the Survival Index method in a formal mathematical way. One technique is based upon maximizing a likelihood function, the other on minimizing the sums of square of differences between observed and expected catches at age. Cooke's paper describes simulation trials which indicate that the estimates are sensitive to random fluctuations in pup production, and errors in ageing.

The Monte Carlo trials were designed to utilize the catch history and likely range of pup production of the Northwest Atlantic harp seals. Cooke emphasized that the reliability of his estimation techniques with different catch histories would require further examination.

Cooke modified the technique to allow for errors in ageing using the information in Doubleday and Owen (1980). He emphasized that their error matrix involved only the minimum level of error as it was concerned solely with inter-reader variations.

The paper investigated the sensitivity of the estimate to violation in the underlying assumption that pup production was constant. Cooke concluded that if pup production was increasing or declining the estimate obtained would be an overestimate of new pup production and be close to the value associated with the pup production in the higher years.

Although Cooke had calculated confidence regions for his estimates, he indicated that these were underestimates of the true levels.

Ugland (this meeting) described a similar method for calculating pup production independent of an estimate of M, which differed mainly in the way in which selectivities were calculated. This method is described in more detail in Section 2.2.

2.2 Estimates of Pup Production and Trend or Natural Mortality

These techniques fall into two groups.

The first group uses statistics from catches at age data to obtain estimates of parameters such as pup production and M using a dynamic population model. These methods include the work of Beddington and Williams (1980) and, at this meeting, Jacobsen, Ugland, and De La Mare.

Beddington reported on simulation studies carried out by De La Mare (this meeting) on the problem of jointly estimating M and pup production. The results indicated that estimates of pup production and mortality were confounded. Accordingly he recommended that estimates based on such joint estimation techniques were unreliable. Recognizing this confounding, the Working Group considered that previously reported estimates of M by such methods should not be considered.

Ugland (this meeting) described a least squares method which seeks a population trajectory giving the best fit to the observed age group frequencies in the catch. Each age group is assigned a selectivity coefficient (see Appendix III). The method may be used to estimate either average pup production and rate of change in pup production, or initial pup production and average M. The selectivities are expressed as functions of the chosen parameters and are not free variables in the minimization of the sum of squares.

Simulations showed that the estimate of the average pup production is robust and almost independent of M, but the estimate of the rate of change in pup production is not robust. In order to estimate M and the current trend in pup production, the method requires at least two sets of age samples separated in time.

The second group of methods uses statistics derived from catches at age and independent estimates of abundance to estimate pup production and M.

Roff and Bowen (this meeting) presented a revised version of their previous analysis (Ross and Bowen, 1981) without substantial change. The basis of the method is an estimation of likelihood values across combinations of M and 1967 pup production. For every trajectory there is an associated probability density based on the probability density functions for estimates of pup productions in 1978 and 1979, and for estimates of the ratio of pup escapements in 1967/68 and 1971/72.

The 1967 age distribution of the population was estimated by calculating correction factors for the catches at age in the years preceding 1967, and by adjusting for the pup kills in these years. The sensitivity of this analysis to the initial age distribution was examined by projection using two different 1967 age distributions. The Working Group concluded that more work is required to establish the statistical properties of the method of obtaining the initial age structure, and that, as indicated by the authors, their confidence intervals for the estimates of pup production and M were too narrow.

2.3 Mark and Recapture Analyses

Bowen and Sergeant (this meeting) reviewed estimates of harp seal pup production using a modified Peterson mark and recapture method. Major tagging experiments aimed at estimating pup production were conducted in March 1978, 1979 and 1980. In addition, tags were applied in the Gulf of St Lawrence in 1977 to study migration patterns. Model assumptions were tested where possible, and estimates were corrected for tag loss and non-reporting of recovered tags. Estimates of confidence intervals accommodated variability in the estimates of these corrections. Estimates from recoveries of tags in the year of tagging were shown by the authors to be unreliable due to non-random mixing of tagged and untagged seals. Based on tests for differing recapture ratios of seals tagged on the Front and in the Gulf, the authors considered estimates of production based on long-term recoveries to be more reliable. From these long-term recoveries, pup production was estimated for 1978, 1979 and 1980. A pup production estimate for 1977 was also provided, but was considered to be unreliable by the authors. Both the authors and the Working Group noted that the calculated confidence limits did not accommodate errors in estimated catches of 1, 2 and 3-year-old seals. The Working Group noted that the test of the assumption of random sampling of long-term recoveries was not as powerful as that applied to recoveries within the year of tagging.

2.4 Aerial Surveys

The results of ultraviolet photographic surveys for harp seal pups in 1975 and 1977 (Lavigne, et al 1980) were considered. Their figure of 250,000 for pup production was the sum of an estimate of 204,000 from an aerial survey of the Front in 1977 and an estimate of 46,000 from an aerial survey of the Gulf in 1975. The Working Group agreed with the authors' observation that this combination of estimates assumes no difference in the proportion of harp seals in the Front and Gulf areas in 1975 and 1977 and does not account for any changes in the number of seals whelping in the Gulf which may have occurred since 1975. If the foregoing assumptions are correct, the total estimate must be low since 48,748 young of the year were caught in the Gulf in 1978 and more than 4,000 tagged pups escaped the hunt.

The Working Group noted that the particular aerial survey technique used in 1975 and 1977 underestimates pup production unless all patches of pups are located and photographed and suitable adjustments are made for the completeness of whelping in the patches surveyed. The difficulties of controlling all sources of error in such surveys are illustrated by the failure to photograph a concentration in the Gulf in 1977 due to navigational error.

The Working Group noted that visible spectrum aerial surveys for hooded seals were carried out in the Davis Strait by MacLaren Marex Inc. (1979) - see Section 3.2 of this report.

Recognizing the potential bias of the available estimates from these surveys, and having no means to determine its extent, the Working Group did not consider them further.

3. HARP AND HOODED SEAL ASSESSMENTS

The Working Group considered the specific questions set out in the terms of reference for harp and hooded seals separately. The results of these considerations are dealt with below.

3.1 Harp Seals (Phoca groenlandica)

3.1.1 History of Exploitation

Harp seals have been hunted commercially in the northwest Atlantic since the 16th century. The offshore hunt began in 1794 and reached a peak between 1825 and 1860 with catches exceeding 500,000 animals (including some hooded seals) in eleven of those years. From 1863 to 1894 the catches dropped to an average of 341,000 (again including some hooded seals). From 1895 to 1911 catches of harp seals averaged 249,000, between 1912 and 1940, 159,000, and between 1949 and 1961, 310,000 animals. The harvest declined to an average of 287,000 from 1961 to 1970. Quota management was introduced in 1971, leading to reduced catches, which averaged 172,000, including 133,000 pups, up to 1981.

In the West Greenland area, catches of harp seals were high in the middle of the 19th century (estimated at 27,000-37,000 animals annually), but they apparently declined towards the turn of the century. During the first decades of the 20th century, catches increased again, reaching a level of approximately 20,000 in the 1930's and 1940's (Kapel 1978). The average catch was 16,400 in the 1950's, 11,000 in the early 1960's, 6,500 in the years 1965-1971 and 7,600 in 1972-77. Preliminary figures indicate that catches have increased to more than 10,000 in the most recent years 1978-1981.

3.1.2 Pup production and population abundance

Estimates of pup production and, hence, population abundance were available for the 1960's and 1970's. Inferences about the 1982 abundance of harp seals involve projections from the late 1970's. Accordingly, the Working Group considered that the questions of yield levels and trends in abundance were best addressed by comparing pup production and abundance estimates for the late 1960's and for the years 1977-80.

Abundance estimates for the late 1960's

The Working Group considered published estimates of pup production by Benjaminsen and Øritsland (1975), Winters (1978), and Lett et al (1979). It noted that Benjaminsen and Øritsland's lower estimate of 300,000 approximated the estimated catch of the 1967 year class.

New estimates were also presented at this meeting. In his paper, Cooke indicated that, if the assumption of constant pup production was violated by a decreasing trend, his estimate would be

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associated with an early year class in the series analysed
and if there had been an increasing trend, with a later year
class. Accordingly, it was agreed that the upper confidence
limits that Cooke obtained for the 1968-77 year classes could
be considered as an upper bound for pup production in the late
1960's. Ugland's analysis, which did not assume a constant pup
production, gave a similar upper bound. It was thus agreed that
a likely range for pup production in the late 1960's was
320-420,000, a range that includes all the point estimates shown
in the following table. The Working Group recognised that doubt
had been cast on the reliability of the estimates which used the
traditional Survival Index method, but noted that these estimates
fall within the above range.

Estimates of Pup Production in the late 1960's

Source	Point Estimate	Upper	Lower
Lett et al (1979)	363	-	-
Winters (1978)	393[1]	-	-
Benjaminsen & Øritsland (1975)	380[1]	-	300[2]
Roff & Bowen	380	-	-
Cooke	293-374	410	270
Ugland	400	428	372

[1] From Survival Indices

[2] Catch of 1967 year class

These pup production estimates were multiplied by 3.75, a very
coarse approximate figure derived from the Roff and Bowen analysis,
to give a corresponding range of 1.2-1.6 million for the 1+
population size in the late 1960's.

Abundance estimates for the late 1970's

Point estimates of pup production for 1977-80 from Lavigne et al
(1980) and presented at this meeting are given below:

Estimates of Pup Production in the period 1977 to 1980

Source	Point Estimate	Upper	Lower	
Ugland	390	-	-	
Lavigne et al	250	-	-	
Bowen and Sergeant	455-516	629	337	(1978-80)
pooled	438	497	379[1]	(1977-80)
pooled	496	570	422[1]	(1978-80)

[1] Modified to accommodate age sampling errors

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It was agreed that the mark and recapture figures provided acceptable estimates. Bowen and Sergeant (this meeting) had given plausible reasons why their estimate of pup production for 1977 applied only to a portion of the total population. However, the Working Group concluded that the basis for this conclusion could not be rigorously established. Therefore pooled estimates for the periods 1977-80 and 1978-80 were calculated, weighting each estimate by the reciprocal of its calculated variance. As noted in Section 2.3, the variances calculated by Bowen and Sergeant did not accommodate the fact that the size of the recapture sample had been estimated. New confidence limits were calculated on the assumption that allowance for this extra source of variation would increase the variance by 30% (Harwood and Hiby - this meeting). For the reasons discussed in Section 2.4, the estimate of 250,000 from the aerial survey was considered to be an underestimate.

Thus, the Working Group concluded that pup production for the period 1977-80 was likely to be in the range 380-500,000. These pup production estimates were multiplied by 4.0, a very coarse, approximate figure derived from the Roff and Bowen analysis, to give a corresponding range of 1.5 million to 2.0 million for the 1+ population in 1977-80.

3.1.3 Trends in pup production and population size

The Working Group considered the implications of the above estimates of pup production for the late 1960's and for 1977-80 on trends in pup production and population size. As indicated below, the ranges of pup production and population size overlap.

Year	Pups (thousands)	1+ (millions)
Late 1960's (modified survival indices)	320-420	1.2-1.6
1977-80 (mark and recapture)	380-500	1.5-2.0

The Working Group noted that the estimates of Cooke and Ugland and the mark and recapture estimates have what statisticians call a central tendency. This means that estimates close to the calculated value are more likely than are estimates far from it. However, the Working Group noted that both estimators are subject to unknown biases which may be in opposite directions. Thus, while the extreme values are not considered as likely as intermediate values, the Working Group did not attempt to quantify this tendency in probability terms.

Recognizing that comparisons between the two ranges of estimates must be made in the context of possible unknown biases in both methods of estimation, the Working Group concluded that the pup production in 1977-80 and 1+ population was likely to have been larger than the late 1960's pup production and 1+ population, but the possibility of no increase or a slight decline is not negligible.

The Working Group noted that the reduction in catches from 1972 onwards would not be expected to influence trends in pup production until 1977 and onwards, as the more abundant post-1972 year classes became sexually mature. The Working Group also noted that anecdotal information from Greenland hunters and catch statistics presented by

Kapel (this meeting) indicate that harp seals were becoming more readily available at West Greenland. Further, analysis of the age structure of catches of harp seals at Northwest Greenland since 1972 indicate good survival of year classes in the late 1970's.

3.1.4 Replacement yield

Replacement yield estimates are sensitive to the specific population trajectory from 1967. In order for the trajectory to pass through the late 1960's and 1977-80 ranges of stock size, various ranges of M are implied. Other values would cause the trajectories to be either too high or too low in later years. The range of feasible values of M is about 0.08 to 0.11.

An equation to calculate replacement yield is given by Roff and Bowen (1981 eq. 26). For this, stock size, pup production, M_{1+}, and M_0 (see Appendix III) are needed. If pup production is taken as the highest (500,000) and lowest (380,000) values of the 1977-80 range, for various combinations of M_{1+} and M_0, the corresponding replacement yields for 1977-80, assuming the continuation of the current 80:20 proportions of pups to 1+ animals in the harvest, are given below:

Pup Production (thousands)	M_{1+}	M_0	Replacement Yield (thousands) 1977-80
500	0.08	0.08	330
500	0.08	0.24	290
380	0.11	0.11	201
380	0.11	0.312	165
380	0.10	0.30	175

These figures are intended to illustrate combinations of M_{1+}, M_0, and pup productions for 1978 which are consistent with the advised ranges of pup production in the late 1960's and in 1977-80. In the years 1977-80, actual harp seal catches ranged between 167,000-187,000 seals.

3.1.5 Sustainable yield

The Working Group considered that it was not feasible to calculate estimates of sustainable yields at this meeting. There were two principals reasons for this. Firstly, forecasts of future vital rates were not available so that assumptions must be made regarding trends in vital rates. Secondly, the Working Group did not have access to the necessary computer programs. Nor was it considered feasible to calculate the implications of its advice concerning population size in the late 1960's and 1977-80 on trends in population size and replacement yield in 1982 and beyond. Thus,

Item 3 of the Terms of Reference was not addressed. However, the Working Group noted that, if the vital rates prevalent in the early 1970's continued to apply indefinitely, then sustainable yield would be greater than the replacement yields calculated for the late 1970's. This is due to the increased number of surviving pups in 1972 and onwards (relative to earlier years) which began to enter the mature population in 1977, so that the population age distributions of the late 1970's had a higher proportion of immature animals than does the stable age distribution with the same schedule of vital rates.

3.2 Hooded Seals (Cystophora cristata)

The Working Group considered the available data relating to the demography of the hooded seal in the Northwest Atlantic.

3.2.1 History of exploitation

Historical catches at Newfoundland fluctuated around 15,000 from 1900 to 1920, but thereafter declined to about 1,000 per year until the 1950's when catches fluctuating about 11,000 were again common. Catches at West Greenland were estimated at about 15,000 in the period 1880-1900, declining to around 4,000 in the 1920's, 1,200 in the 1940's and 800 in the 1950's (Kapel, 1978). Norwegian catches at moulting areas in the Denmark Strait fluctuated around 15,000 from 1945 until 1960, when the fishery was closed apart from some relatively small catches by Greenland.

Recent catches, including those at Greenland, have averaged approximately 15,000 animals, comprising about 60% pups and 30% 1+ females. Annual removals of females have declined from about 4,000 animals prior to the introduction of limitations on the kill in 1977, to about 2,000 animals since then.

3.2.2 Stock relations

Available data on recoveries of tagged hooded seals indicate movements between Newfoundland, Greenland and the moulting patches in the Denmark Strait. Limited tagging of hooded seals at Jan Mayen has not demonstrated any movements of seals from that stock westwards beyond the Denmark Strait.

In 1974 an additional breeding herd of hooded seals was rediscovered in the Davis Strait. Its presence has subsequently been confirmed by aerial surveys but its relation to the harvested population is unknown.

3.2.3 Mortality, pup production and population trends

The Working Group reviewed a variety of documents relating to the the production and mortality of Northwest Atlantic hooded seals. Pup production estimates from techniques using catches at age were not available for the 1970's. Several point estimates for pup production in the mid-1960's, from a variety of techniques, were presented (Jacobsen and Øritsland, 1982; Goodman, Winters et al - this meeting). Individual estimates ranged from 27,000 to 41,000. Confidence intervals for these estimates, where they had been calculated, were very wide.

Estimates of total instantaneous mortality for breeding females during the period 1966-1980 varied between 0.19 and 0.25. Estimated mortality rates levels decreased substantially in most recent years and this is consistent with the reduced kill of breeding females since 1977.

MacLaren Marex Inc. (1979) carried out visual spectrum photographic surveys of hooded seals in the Davis Strait in March 1977 and 1978. They estimated that one patch in 1977 had 13,000 pups. A corresponding estimate for 1978 was 11,700 pups. The Working Group had no opportunity to discuss these surveys.

The Working Group considered various sources of ancillary data relating to possible trends in hooded seal abundance. Catches of hooded seals from Greenland have increased since the 1960's and Kapel reported anecdotal information from hunters on increased abundance at Greenland in recent years. Interpretation of this information is not clear, however, because changes in availability (as a result of distributional changes) rather than abundance could also produce increased catches. Winters reported that catch rates of Norwegian vessels at the Front, adjusted for known changes in hunting efficiency, have increased steadily in the past several decades.

The Working Group concluded unanimously that the analyses of available data are insufficient to provide reliable estimates of current pup production, stock size and vital rates for the hooded seals population in the Northwest Atlantic; and hence to determine population trends on that basis. This conclusion also applies to the evaluation of the present management measures in the Denmark Strait and the Northwest Atlantic.

4. EFECTS OF CHANGES IN FOOD SUPPLY

The request for advice on this topic seems to be prompted by two concerns: a general concern that the vital rates of harp and hooded seals are unlikely to remain constant if the food supply available per capita changes; and a specific concern because stocks of capelin (Mallotus villosus) - a species commonly consumed by harp seals - in the Northwest Atlantic suffered a major decline in the late 1970's.

There may no longer be a cause for the latter concern. The most recent meeting of NAFO's Scientific Council (NAFO SCS Doc. 82/VI/18) advised that by 1982 capelin stocks in NAFO areas 2J and 3K - a major feeding locality for harp seals in the period before and after whelping - will have recovered to their levels in the 1960's. No assessments have been made for capelin stocks in the Gulf of St Lawrence and off West Greenland. The Working Group noted that capelin is a species with a short life span, so that natural fluctuations in recruitment will be reflected in the stock biomass level.

Stomach samples of hooded and harp seals from Newfoundland, Greenland and the Northeast Atlantic indicate that both species are opportunistic feeders and may be able to compensate for changes in the relative abundance of their preferred food species. However, it is extremely difficult to quantify the diet throughout their entire feeding range.

With current knowledge, reliable prediction of trends in the vital rates of harp and hooded seals is not feasible. It is therefore important that monitoring of vital rates should continue. This is especially important for hooded seals where estimates of vital rates are based on smaller sample sizes than for harp seals.

5. FUTURE RESEARCH

5.1 Statistics of Estimation

All estimation schemes are based upon simplifying assumptions, which may be violated. For procedures using catches at age, these include constant natural mortality rates and age-specific sampling selectivities. For mark and recapture studies, they include uniform mixing of tagged and untagged animals, constant return rate of tags recovered, and equal survival probabilities of tagged and untagged animals. It is difficult to assess the magnitude of deviations from such assumptions, and their effects upon estimation schemes.

A commonly accepted practice has been to test only the null hypothesis of no significant deviations from such assumptions. Such a procedure neglects such deviations, unless the evidence to the contrary is statistically significant. A more rigorous approach is as follows: test a family of hypotheses, which depend upon a parameter d. The case $d = 0$ would correspond to the null hypothesis of no deviation from the assumption.

Increasing magnitude of d would correspond to increasing deviation from the assumption. A significance test can be employed to reject values of d outside an interval (d_1, d_2). Then the performance of the estimation scheme (bias, efficiency) can be assessed for all values of d between d_1 and d_2. Ordinarily, this will be done by means of simulation studies (see below). The result of such a revised procedure is to examine the effects of wide deviations from the assumptions when there is little information on their validity, and to narrow down the possibilities where warranted.

The Working Group concluded that simulation trials are an effective means of assessing the sensitivity of estimation procedures to departures from assumptions. Although mathematical derivations are desirable in order to compare schemes and evaluate their properties, the ultimate test requires an assessment of robustness. It is recommended that the magnitudes of likely deviations from simplifying assumptions be estimated as indicated above. Then the consequences of such deviations can in turn be assessed by simulation studies. It is recommended that a standardized set of such simulations be employed in the future.

5.2 Population Estimation

5.2.1 General

It was noted that the modified Survival Index methods using maximum likelihood or least squares techniques were sensitive to catch history. This rendered them sensitive in varying degrees to such problems as ageing error and trends in pup production. The Group recommended that a sensitivity analysis along the lines indicated above would increase the usefulness of these techniques. Similarly it was noted that the confidence regions obtained by these techniques were approximate and that simulation studies should be extended to assess these limits more closely.

It was noted that modified Survival Index methods could be
used to estimate population abundance in different periods and
that a method similar to Roff and Bowen's might then be used to
estimate trend or M during the intervening period. Such methods,
which utilize estimates from different groups of techniques (as
described in Section 2) are vulnerable, in principle, to opposing
biases in the different estimates.

5.2.2 Harp seals

It was noted that a continuation of the age sampling programmes
and of the mark and recapture studies is essential to the future
assessment of the population.

5.2.3 Hooded seals

The modified Survival Index methods of population assessment are
dependent on catch at age samples and a variable catch history
for pups. The particular catch history for hooded seals in the
Northwest Atlantic has not permitted a reliable population assess-
ment. Increased variability in the pup kills would improve the
accuracy of such estimates in future; a similar argument applies
for harp seals. The Working Group emphasizes that continued
sampling of the catch is essential if the status of the stock is to
be evaluated in the future.

It was noted that an aerial survey was planned in the Newfoundland
area in the coming season. The Working Group strongly endorsed
this plan. The Davis Strait breeding herd may have significant
implications for the management of the Northwest Atlantic hooded
seal stock, and therefore increased research on this herd is
desirable. This should include extension of the Newfoundland
aerial survey to include the Davis Strait, as well as tagging
experiments and the collection of biological samples.

5.3 Vital Rates

Estimates of replacement yield and sustainable yields depend on values
for vital rates and their trends. As noted in Section 4, these cannot
be predicted at present. Therefore the Working Group repeats its
recommendations that monitoring of vital rates by biological sampling
for both species should continue. It further recommends that, because the
survival rate of pups is difficult to monitor directly, analysis of the
condition of pups should continue.

APPENDIX I

List of Participants

W D Bowen   Canada
W G Doubleday   "
D Ludwig   "
D A Roff   "
G H Winters   "

F O Kapel   Denmark
F Larsen   "

H E Drescher   Federal Republic of Germany

P J H Reijnders   Netherlands

N O Jacobsen   Norway
T Øritsland   "
K I Ugland   "

J R Beddington   United Kingdom
J Harwood   "   "
J W Horwood   "   "
B B Parrish   (Chairman)   "   "

D Goodman   USA
Ch. Fowler   "

APPENDIX II

References

Papers presented to the Working Group meeting*

Goodman, D.   Analysis of the harp seal management models.

Goodman, D.   An assessment of the status of the Northwest Atlantic stocks of hooded seals.

De La Mare, W K. The estimation of the dynamics of exploited seal populations from the analysis of age data.

Cooke, J G.   Application of the modified survival index method to Northwest Atlantic hooded seals.

Cooke, J G.   An investigation of the survival index method of population estimation with particular reference to Northwest Atlantic harp seals.

Kapel, F O.   Trends in catches of harp seals in West Greenland.

Ugland, K I.   Abundance estimation of the Northwestern Atlantic harp seal population.

Jacobsen, N O.   Estimates of pup production, age at first parturition and natural mortality for hooded seals in the West Ice.

Winters, G H, Hay, K and Bowen, W D. Review of the demography of hooded seals (Cystophora cristata) in the Northwest Atlantic.

Harwood, J and Hiby, A R.   Comments on recent estimates of the size and status of the Northwest Atlantic harp seal stock.

Roff, D A and Bowen, W D.   A maximum likelihood method for estimation of population size and natural mortality of harp seals.

Bowen, W D and Sergeant, D E. Mark-recapture estimates of harp seal pup production in the NW Atlantic.

Ugland, K I.   Mathematical justification of the survival index method.

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*Readers of the report wishing access to any of these papers should
contact the authors concerned.

APPENDIX III

Glossary

1+   -   Refers to total population immediately prior to whelping (February)

M   -   Instantaneous annual relative natural mortality rate for all ages

M_0 -   As for M, but applying only to pups

M_{1+} -   As for M, but applying only to animals aged one and older

Selectivity   -   at age i refers to proportion of age i in catch divided by proportion of age group i in 1+ population

Replacement yield   -   Catch which may be taken during one year to result in same 1+ population in the following year

Survival Index   -   A series of indices are calculated for a year class at successive ages i in successive years t as

$$S_i = \frac{A. \sum B}{\sum B_t . \sum A}$$

where A = catch of age i seals in year t

$\sum B_t$ = catch of all ages 1 and older in year t

$\sum A$ = total catch of age i for all years

$\sum B$ = total catch of all ages 1 and above for all years

The survival index for the year class is a weighted average of the S_i's.

Indication of spine colours

Reports of the Advisory Committee
on Fishery Management .... Red

Reports of the Advisory Committee on
Marine Pollution .... Yellow

Fish Assessment Reports .... Grey

Pollution Studies .... Green

Others .... Black

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