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REPORT OF THE ICES/NAFO WORKSHOP ON SURVEY METHODOLOGY FOR HARP AND HOODED SEALS

SevPINRO, Archangelsk, Russia - 5-12 October 1992

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1. TERMS OF REFERENCE

The Workshop was arranged following a recommendation by the Joint ICES/NAFO Working Group on Harp and Hooded Seals (ICES C.M. 1992: Assess 5). The purpose was to provide an international forum for the discussion of current survey methods in order to identify techniques applicable for estimating the abundance of harp and hooded seals.

During preparation, it was suggested that the specific goals of the Workshop would be to:

1) review historical Russian, Norwegian and Canadian surveys of harp and hooded seals and compile a comprehensive description of survey methods used in the past 10 years;

2) review current survey techniques (e.g. visual surveys, ultraviolet photography, thermal imagery) and discuss their applicability to harp and hooded seals;

3) review survey designs and statistical methods used to estimate abundance of seals.

Drs G.B. Stenson, DFO, St. John's, Canada and Yu.K. Timoshenko, SevPINRO, Archangelsk, Russia were appointed as co-convenors of the Workshop.

2. MEETING ARRANGEMENTS

The Workshop was held at the Northern Branch of the Polar Research Institute of Marine Fisheries and Oceanography (SevPINRO) in Archangelsk, Russia, and was organised in two sections:

a) 5-7 October were used for informal consultations between participating scientists, divided in two groups: an administrative, planning group consisting of the co-convenors Drs G.B. Stenson and Yu. K. Timoshenko assisted by Dr. L.A. Popov and Mr. F.O. Kapel to develop the agenda and working schedule of the Workshop, and a technical group to clarify technological and methodological details relating to current aerial surveys of harp and hooded seals. The findings of the latter group are reflected in the following report.

b) 8-10 and 12 October were then devoted to formal presentations of written or verbal contributions, and to discussions of related problems. For this part of the Workshop, F.O. Kapel was elected chairman, and W.T. Stobo rapporteur.

The present report contains abstracts of the presentations, resumés of the discussions and considerations of future activities relevant to the purpose of the Workshop. The agenda is given in Appendix 1, the participants are listed in Appendix 2, and a list of documents is presented in Appendix 3.

3. REVIEW OF CURRENT SURVEY METHODS FOR HARP AND HOODED SEALS

Yu.K. Timoshenko: Methods of harp seal stock assessment in the White Sea (Doc. 1).

Abstract: Aerial surveys of pup patches were conducted in order to assess harp seal abundance in the White Sea. The following equipment was used: planes IL-14 or AN-30, camera AFA-42/20, film 32 x 600 cm (size of frame 30 x 30 cm). Flight altitude was 400 m, scale 1:2000. The biological basis for using aerial survey photography is that whelping female harp seals form highly-concentrated patches in well-defined areas of the White Sea. Patches, formed far away from the edge of the ice remain stable for some time. Problems of further patch-drift is sufficiently investigated. Patches were photographed by means of line transects. Methods, where all the discovered patches were attempted covered by photographing, were also used (1980 and 1985). When it was not possible to cover all discovered patches, an index of female density was extrapolated to the total area of patches (1988 and 1991). The numbers of whelping females assessed on the ice were: 1980 138 551, 1985 139 387, 1988 138 561, 1991 141 667.

Discussion centered around the discreteness and long term integrity of whelping patches and the counting method. Reconnaissance flights are conducted early in the season and continue until just prior to the photographic surveys. Although some whelping patches form later than others and in some years considerable ice drifting and movement occurs, the total area to be surveyed is relatively small and has been studied for many years. This historical information and the reconnaissance flights provide confidence 1) in the designation of discrete whelping patches even though the photographic surveys can last several days, 2) that redundant coverage of whelping patches does not occur and 3) that no whelping patches are missed.

In reading the photographs, only adults are counted; pup numbers are then determined from the number of mature females in the photographs. Since the males concentrate more tightly, are usually found near the ice edge, and have a different appearence in the photographs, the author does not believe that there is a substantial problem in distinguishing mature females.

V.A. Potelov and V.I. Chernook: Hooded seals stock assessment in the Greenland Sea (Doc. 3).

Abstract: In 1986-1989 aerial photographic surveys of hooded seals in the Jan Mayen area were conducted from a IL-18 DORR aeroplane, based in Murmansk. Various types of cameras including video cameras were used during the surveys. Simultaneously, visual estimates were conducted. Visual estimates were conducted on both sides of plane. The observed strip width was equal to two times the flying altitude (200-300 m). Information, received from 2 observers, was then entered into a PC. Data on coordinates and flying altitude of the plane was automatically entered into the PC.

When a hooded seal patch was discovered, its borders were determined, and aerial line transects were then set on the patches. Immediately after the aerial photography was over, rough estimates of the numbers of hooded seals on the patch were done by the PC. When returning to Murmansk, information obtained on from the visual observations was taken into consideration, and seal density on the transects observed and the rough estimates of seal abundance were corrected. Information about the rough seal stock assessments, patch allocations, ice conditions was transmitted by radio to commercial vessels.

After the return, all information including line transect aerial surveys, was processed to obtain corrected estimates of total hooded seal abundance.

There were some problems, when conducting these studies:

- the discovered hooded seal patches were not highly concentrated, so it was difficult to determine their borders;
- lack of information on ice-condition and patch allocation in this area causes considerable waste of flight time;
- the considerable distance between the survey area and the plane base (it takes 70 % of all flight time only to get to area of survey) resulted in only a small number of aerial survey line transects on patches, due to lack of time.

All these problems may cause errors in the assessment of hooded seal stock abundance in the Greenland Sea.

The main difficulty in surveying harp and hooded seals in the Greenland Sea with aerial techniques is their location. Flying duration of the aircraft does not provide adequate time to locate and photograph all of the whelping patches. The photographic results were relied upon to estimate numbers. The video camera was an early model and tended to give blurred images below 200 m, although it functioned well between 200 and 900 m with a telephoto lens. The use of the thermal imager was experimental.

N. Øien: Norwegian surveys in the Greenland Sea.

Abstract: A survey program of harp and hooded seals in the Greenland Sea was initiated in 1990 with a feasibility study of using aerial video and still-photo cameras to determine abundances. The experience gained from this study was used in conducting a survey of harp seal breeding patches in 1991, as we found it difficult to work with both species at the same time. There were several elements of the survey:

Photographic surveys were made from a Partenavia P 68 TC Observer based at Jan Mayen. The plane was equipped with a vertically mounted Wild RC20 (f=15.3 cm) as the main camera and an additional Vinten F95 (f=35 cm). Reconnaissance flights were flown at altitudes in the range 250-1000 feet, depending on weather conditions, while photographic flights were done at altitudes around 150 m and speeds 100-120 knots. Photographs were taken while flying equally spaced transects through the breeding patches. Pups have been counted from negatives over a light table, using a magnifying lens.

Visual surveys were made from a helicopter (AS 350 B1 Ecureuil) flown at an altitude of 200 feet above the ice. Observations were made trough funnelshaped devices mounted on each side of the helicopter, allowing for strip widths of 20-30 m. Visual surveys were done at low speed, approx. 30 knots. Transects were evenly spaced or placed at random. Observations were read into a tape recorder connected to a clock.

Stage determinations were made from helicopter at low height. Four harp seal breeding patches were investigated in 1991, of which three received coverage from photographic and three from visual surveys. The data analyses are not finished.

In discussing procedures during the survey, it was indicated that total flying time was about 45 hours of which 20 hours were used for reconnaissance. Radio buoys were placed in the main whelping patches to monitor drift. In staging pups the classification procedure used was the same as that used in the Northwest Atlantic; no groundtruthing of the photographic counts occurred. The video camera data was transferred to a computer and processed by software developed in Bergen; it is not yet generally available for use. It was noted that the estimates from the photographic survey appear to be lower than the visual estimates, but the difference is not significant.

G.B. Stenson: Methods of estimating pup production of harp and hooded seals in the Northwest Atlantic (ref. Docs 4 & 11).

Abstract: Over the past 40 years a variety of methods have been used to estimate the abundance of harp and hooded seals in the northwest Atlantic. Estimates of pup production were obtained using aerial surveys, mark-recapture experiments and age composition data. The most recent estimates were obtained in 1990 and 1991 using aerial survey techniques. Harp seal pup production was estimated in the Gulf of St. Lawrence ('Gulf') and at the 'Front' during 1990 (Doc. 4) while hooded seals were assessed in both areas in 1990 and in the Gulf only during 1991 (Doc. 11).

Whelping concentrations were located using fixed-wing and/or helicopter reconnaissance surveys of historical areas. In 1990, a total of 3 harp and 2 hooded seal concentrations were located off Newfoundland ('Front') while in the Gulf of St. Lawrence, 1 harp and 1 hooded seal concentration were located near the Magdalen Islands in the southern Gulf and a second harp seal concentration was found in the northern Gulf. In 1991, 2 hooded seal patches were located in the southern Gulf. Systematic aerial photographic surveys were flown at an altitude of 305 m using a standard 23 x 23 cm format aerographic camera during 1990 only. Imagery was also obtained using a Vinten 70 mm aerial camera equipped with a quartz lenz and ultra-violet filter. Two strata were identified at the Front, whelping concentrations (high density), and scattered pups

outside whelping patches (low density) while the entire areas around the whelping concentrations were surveyed in the Gulf. Abundance was estimated from the sum of pups on the photographs over all transects, correcting for non-overlapping photographs and the transect spacing. The estimates of error variance were based on serial difference between transects.

The number of pups on each print was corrected by comparing identical areas on the black-and-white and ultra-violet imagery. Individual seals on each image were compared to determine if any pups were missed or misidentified and the actual number of seals present was determined. Counts from each reader were regressed on the counts determined from the matched photographs to develop a correction factor which was applied to each of the original photo counts independently for each reader. The error associated with these corrections was calculated using bootstrap estimation procedures and was added to the sampling variance.

Visual surveys were conducted for both species at the Front and for hooded seals only in the Gulf. For harp seals, the surveys were flown using ship-based helicopters at an altitude of 46 m with a transect width of 30 m on each side. Techniques varied slightly for hooded seals but the majority of surveys were flown at 30 m with a transect width of 100 m per side. The analysis was the same as used for the photographic surveys, assuming complete coverage along a transect.

The proportion of pups in age-dependent stages on various days was used to model the distribution of births throughout time. This model was then used to correct the estimate for pups which may not have been born or which may have already left the ice. Details are given in Section 6 (Warren). Prior to the surveys, personnel from both the Front and Gulf areas standardized stage determinations to ensure observer consistency. For harp seals, random points within each concentration were chosen and at each point samples of pups were classified by personnel walking on the ice. This was repeated throughout the survey period. Hooded seals were classified during the visual surveys. The 100 m transect width was divided in half and all pups present within the inner 50 m were classified.

Discussion centered on the techniques used. Approximately 50 hours of fixed wing aircraft flying time was used for reconnaissance and 90 hours for photography. The visual estimate survey for harp seals was conducted with a helicopter flying at an altitude of 46 m; although the pups were disturbed by the helicopter, they did not go into the water and it may have improved the visual counts since the pups often moved, and pups hidden in shadows or by overhangs often became exposed by moving. The flying altitude was chosen because in earlier attempts at greater heights it was difficult to see all the pups. The speed of the helicopter was also variable to ensure all the pups in a transect were counted. Although a correction factor for hidden pups was used in the 1983 assessment, in 1990 it was so small that none was used; this difference, however, does emphasize the value of groundtruthing every survey to assess the correction factor required. The amount of correction necessary can be highly influenced by ice conditions. Heavy rafting or ridging could substantially influence the count - especially of pups, and could also increase pup mortality. Hooded seals seem to prefer heavier ice than harp seals.

General discussion: Following the four presentations, many discussion points were repeated and generalized. It is necessary to conduct reconnaissance flights prior to the estimation surveys to evaluate the distribution, sizes and locations of the whelping patches, and the amount of time spent in reconnaissance will vary with area. It is also necessary to determine when to conduct the estimation surveys, so that it is near peak pupping. In the White Sea the area is relatively confined so the main problem is determining when to conduct the survey. In the Northwest Atlantic, however, finding and delineating the patches is a prime problem because of the variation between years.

Weather conditions can influence the surveys in several ways. Heavy winds cause ice drift resulting in patch dispersal or merging between the time of the reconnaissance flights and the esimation surveys. Wind can cause ice rafting and thereby increase the number of hidden pups, or pup mortality. Overcast days, or conducting photography at low sun inclination levels could make pup/adult detection more difficult in the photographs. If adults rather than pups are being counted, time of day can also be an important factor, for example females may be more prone to be on the ice in morning than in the afternoon. This behavioural factor could cause bias or more variability in estimation.

Since pupping occurs over an extended period, a single estimation survey may not give a total production estimate. Thus attempts should be made to assess the percentage of pups available on the ice at that time in order to develop a correction factor to estimate total production.

4. REVIEW OF SURVEY METHODS USED FOR OTHER SEAL SPECIES

W.T. Stobo: Validation of aerial photographic estimates of grey seals on Sable Island, Canada (Doc. 10).

Abstract: Grey seal, Halichoerus grypus, pup production on Sable Island was monitored from 1977 to 1990 by complete cohort tagging. In 1989 and 1990, aerial surveys were also conducted to evaluate the potential of complete photographic coverage of the breeding grounds as an alternative procedure to tagging. Those photographic survey estimates were within 4 % and 6 % respectively of the known pup production in 1989 and 1990. A comparison study conducted in 1990 indicated that 95 % of total pup production had occurred by the date of the photographic survey. Thus the aerial surveys give a reliable estimate of pup production and a correction factor for pups born later can be developed to adjust the survey estimate to total production.

Examination of the reader's ability to distinguish pups on the negatives indicated that pup counts increased with experience in reading the negatives but became relatively constant after 3 readings of color negatives; pup counts continued to increase with black-and-white negatives even after 6 readings.

The reader's ability to distinguish pups on the negatives was further assessed by comparing his pup counts, from the photographs of designated plots (ground truthing areas), to those made by observers on the ground. The ground observations were made at the same time as the aerial photographs were being taken. Overall the reader located 87.5 % of the pups in the black-and-white negatives and 88.6 % in the color negatives.

This study confirmed the validity of complete photographic surveys as a way to monitor grey seal population trends on Sable Island. It also indicated the need to calibrate the accuracy of negative readings by multible readings of a sample of the negatives and by the use of ground truthing areas.

M.O. Hammill: Estimating pup production of ice breeding grey seals in the Gulf of St. Lawrence, Canada (Doc. 12).

Abstract: In Canada there are two major whelping concentrations of grey seals (Halichoerus grypus). One group whelps on Sable Island 160 km off the coast of Nova Scotia. Pup production for this group was 9,712 in 1989 and was increasing at a rate of 12.6 % per year. The second large group of grey seals whelps on the pack ice in the southern Gulf of St. Lawrence. Estimates of pup production from mark-recapture experiments range from 5,295 to 11,694 for 1984 to 1986. An analysis of the distribution of tag recoveries indicates that the assumption of random mixing of tags was not satisfied in all samples. Using only samples satisfying model assumptions pup production for 1984-86 was estimated as 5,233 to 9,618, with 4 of 6 estimates lying between 5,600 and 7,600.
In 1989 and 1990 the mark-recapture experiment was repeated and a new approach utilizing the resighting of marked pups within the whelping patch was developed. Estimated pup production was 8,316 to 10,737 using recapture data from pups several months old. Estimated pup production from the recapture of pups in the whelping patch was 9,804 and 10,134 for 1989 and 1990, respectively.

Discussion on mark-recapture procedures related to multiple recaptures and tag loss. In this study both live captures and 'kill' captures were used to estimate cohort size. Live recaptures can involve multiple recaptures while 'kill' recaptures do not which complicates the analysis. In this case multiple recaptures were avoided by 'paint' marking all tagged seals. Tag loss can be substantial in seals, usually increases with age, and again will complicate mark-recapture analyses. In this study only juvenile seals were used, mostly pups, and tag loss was not significant.

E.A. Petrov: Estimates of pup production of the Baikal seal.

Abstract: Peculiarities of the biology and ecology of the Baikal seal determine the choice of methods for estimating the pup production. The only element which can be accurately identified is a birth lair - the place where a female gives birth and feeds its pup. Studies of estimating pup production in lake Baikal have been carried out since the end of 1960s. The number of pups was estimated as 14-17 thousand up to 1988.

In 1992 a modified method considering the peculiarities of the whelping female distribution was employed and the number of pups was estimated as 14,106 ±2,099 for the southern and middle basins of the lake. In April when it is easy to identify a birth lair, 26 transects are deployed across the ice of the lake. On every transect there are 7 square plots (1.5 x 1.5 km) where birth lairs are counted by observers using motorcycles. The total area of observation is 400 sq. km that is 1.5 % of the whole area of the lake. The choice of transects is determined by longitudinal distribution of whelping females. The main transects are placed in the area with the maximum density of animals and additional transects are placed with defined distances between each other. These distances are calculated on the basis of multi-year data. The position of the plots on every transect is determined by the latitudinal distribution of whelping females.

The estimate of the total number of the Baikal seal population is made on the basis of the data on age-sex structure and the participation of females of different age in reproduction.

The possibility of two or more birth lairs per female was discussed. The frequency with which female Baikal seals build more than one birth lair may change depending on weather conditions. Experienced observers are required on the ground transect surveys to determine the proportion of females having double lairs. This variable tendency for double lairs will be a difficult problem to overcome if aerial surveys are instituted.

O. Svetocheva: Methods of ringed seal (Pusa hispida) stock assessment.

Abstract: Being a typical pagophilic animal, ringed seal can be found everywhere in the Arctic Sea of Russia. The solitary way of life makes ringed seal stock assessment very difficult. In the Sea Mammals Laboratory studies on ringed seal assessment have been conducted since 1974. Various methods have been used:

1. Whelping grounds assessment (the White, Barents, Kara Seas). In order to discover possible areas of concentrations of whelping patches in February, reconnaissance is conducted. Snowtrucks and specially trained dogs are used for assessing ringed seals. Special squares (500 x 500 m) are marked. Another way is engaging two men and a dog in one line transect. Width of the strip observed (up to 200 m) depends upon the dog's ability to track the seals.

2. Aerial survey. 2.1. In the White Sea, aerial surveys are conducted in spring at the end of April on line transects when the coastal ice is melting. Planes and helicopters are used (speed 90-150 km/h, altitude 100-150 m, width of strip observed 2 km). The strip width was determined by flying over two objects, e.g. telegraph poles, the distance between which was determined beforehand. Most often seals are discovered near ice-faults, pools and edge of ice.
2.2. In the East-Siberian Sea, aerial surveys of coastal, snow-covered ice have been conducted since May-June, 1989-1990. The equipment is the same as the one used in the White Sea. In addition to line transects, a square method was used for statistical processing of the information. One flight minute (about 2.5 km), multiplied by the width of the strip observed (2 km) was considered to be a square. Results of these assessments turned out to be similar.

The following methods were also used: a) vessel or cutter surveys (speed 10-15 km/h, width of strip observed up to 200 m);
b) aerial surveys, conducted in the autumn during coastal ice formation in a usual flight regime. These methods give a more complete information on seal distribution.

5. NEW TECHNOLOGY OR METHODS IN AERIAL SURVEYS

G.B. Stenson: The use of ultra-violet imagery for assessing pup production.

Abstract: One major source of error which can occur during the use of photographic surveys is the inability of the person examining the photo to correctly identify the animals present. This may be affected by image quality, flying altitude (image size) or the contrast between the object and its background. This is particularly difficult for white-coated harp seal pups which are hard to distinguish from the ice on which they live. Studies conducted in the mid 1970's indicated that harp seal pups may be distinguished from their background by obtaining imagery in the ultra-violet (UV) range (300-400 nm) which is absorbed by pups but reflected by the background. In 1987, we conducted a study to experimentally evaluate the influence of flying altitude and various combinations of cameras, film, and lens on the visibility of harp and hooded seals.

Two cameras were used, a standard 23 x 23 cm format mapping camera equipped with a glass lens, and a 70 mm format

aerographic camera equipped with a quartz lenz. Flying altitudes ranged from 150-914 m. High speed (320 ASA) black-and-white (B&W), lower speed (200 ASA) B&W, and colour film were compared using the large format camera. The influence of lens type was examined by equipping both cameras with a UV filter. Repeated flights were flown over a transect chosen to obtain the maximum number of pups. All imagery was compared to imagery obtained from the lowest altitude (control) to identify adults and pups present on both the control and experimental transects. The proportion of seals misidentified during a single examination by an experienced reader was determined.
Experimental conditions and overall image quality did not allow us to determine the absolute rate of misidentifications but did indicate general trends. The majority of adults were identified using conventional B&W photography at altitudes up to 600 m. Pups were missed at lower altitudes. The images obtained from the 200 ASA film were superior to those obtained from the faster B&W film. The identification of adults was improved by the use of colour film although pups could not be observed on the film which was slightly over-exposed. The UV filter and glass lens improved the detectability of harp seals slightly but reduced the number of hooded seals identified. The use of a UV filter and quartz lens increased the number of both species detected at all altitudes.
Although the use of ultra-violet photography can improve the visibility of harp seal pups, the reduction in the area of coverage, the smaller image size, and problems with identifying species in mixed groups, limit its usefullness as a primary sensor during large scale surveys. However, it can be used effectively to corrected counts obtained by other sensors.

Various aspects of using ultra-violet photography were discussed, stemming from the problems encountered with the initial attempts to use it in the Northwest Atlantic. New technology has eliminated most of the technical problems previously encountered, and ultra-violet photography is not affected by light and weather conditions to the extent that other photographic methods are. The influence of various filters in conjunction with black-and-white photography is unknown.

V.I. Chernook: Assessment of harp seal abundance by means of infra-red photography during aerial surveys (Doc. 5), and Application of complex automated systems for aerial surveys (Docs 2 and 8).

Abstracts: <u>Doc. 5</u>: Unlike adult harp seals, pups can not be easily seen on ice and snow. The light color of the pup pelt is a masking factor. But in the infra-red range of the spectrum both adult seals and pups have considerable thermal contrast with the surrounding background. We used aerial photography of pup rookeries simultaneously in both the visible and the infra-red range of the spectrum by means of video camera and thermal TV, followed by simul-

taneous processing of photos. Aerial surveys of pup rookeries in the White Sea were conducted. When conducting aerial survey photography, only adult seals were seen clearly in the visible range, whereas whitecoats were invisible on the surrounding background. Conversely, in thermal photos whitecoats and adult seals can rather easily be distinguished; by means of these photos the total number of seals is estimated. Considering that both surveys were conducted simultaneously, the whitecoat stock can be estimated by subtracting the number of adult seals from the total seal stock. A ratio co-efficient between whitecoats and adults is used for assessing the whitecoats stock of all the photographed patches.
The following equipment was used in this method of estimating: video camera, thermal TV, satellite navigation system, IBM PC, aerial survey camera. Recently, studies on automatization of photo processing and assessing of seal stock abundance have been conducted.

<u>Doc. 2</u>: The automated system for aerial survey was developed to increase the effectiveness of searching and photographing sea mammals, especially seals in the periods of concentration in herds, while onboard of the aircraft. The increasing effectiveness is achieved by:

- computerizing of the process of positioning the data coming from the observers during the flight;
- automatic storing of all incoming information into a computer with possibility of retrospective analysis of all recently obtained data (incl. the previous flights);
- automatic combining IR-, video- and photo survey areas to the geographic position and time at which they were made;
- adequate presentation of the data obtained during the flight as a map of the explored region with the entering of conventional signs (symbols) of the discovered objects and their characteristics, flight route and coast line;
- prompt obtaining of hard copies of the distribution maps, that can be handed to the customer.

<u>Doc. 8</u>: This document discusses the main characteristics of a newly-developed system "POMOR", destined for UHF-remote sensing and real-time analysis of sea water and ice conditions, and the possibilities of applicating it for sea mammals environment monitoring.
System "POMOR" includes the following equipment:

- SLAR - Side Looking Air-born Radar (3-sm wave band);
- highly precise satellite positioning system;
- equipment for connecting with aircraft systems and obtaining from them some additional information;
- on-board computers for controlling the measuring and surveying process, gathering and processing incoming information and obtaining final result for end-users in real time scale;
- communication means both for transferring data between computers on board of airplane and for broadcasting results to other ships and on-land facilities.

In addition, the "POMOR" system can be used for searching of regions of sea mammals accumulations, correlated to the most suitable ice conditions, and also for finding sea mammal shoals in open water, because of changes in water-surface roughness. Quick response in obtaining final results permits transfer during flights of all the necessary data to vessels.
Distribution of multi-year ice concentrations mapping in ice-edge region may be used to predict the distribution of hooded seals and to search for them. Having all the information about ice conditions in forms of maps it is possible to predict the distribution of rookeries locations.
During periods of sea mammal hunting the most urgent task is to help ships in finding their way and searching mammals concentrations.

N. Øien: The use of video cameras during seal surveys.

Abstract: The Norwegian survey conducted in the Greenland Sea in 1990 was a feasibility study of the applications of video and photographic techniques to estimate abundance of seals. Based on the results from that survey, Doc. 6 (Estep et al. 1992) considers the use of image analysis of aerial photographs and video as a tool for general analysis of survey data. The video records from the survey were run through a video mixer to stabilize images and remove excessive noise. The negatives from the aerial photographing were transferred to video and went through a set of operations to make image interpretation easier for the operator, remove image noise, and highlight specific features of interest. Analyses were made using the Zeus Image-Analysis System.

Estep et al. give some examples of applications of image analysis: 1) size ice-floes and reveal associations between ice conditions and seal abundance; 2) sizing of individual seals. Aerial photographs were made from 152 m and 305 m altitudes, and video tapes at altitudes 61, 91, 122, 152 and 183 m. The preferred altitude depends on the object of the analysis; ice conditions might well be assessed from high altitudes, while seal sizing requires low altitude as increased resolution is necessary. The feasibility study in 1990 also revealed that video camera performance must be considered, since one of the two cameras applied showed autofocus failure when crossing from ice to open water.

The discussion on this topic related to potential improvements in processing time. Although it had been hoped that using the image analysis system would enhance the speed of processing, preparation of the images for analysis actually increased processing time and hence continuation of this work is not high priority. Further, in order to get sufficient resolution in the photographs to measure seals, the survey has to be flown at heights no greater than 150 m, thus it will not be useful for routine measurements of seals from estimation surveys.

6. METHODS OF ANALYSIS OF AERIAL SURVEYS

A general discussion focussed on the potential problems and errors associated with existing aerial surveys techniques. Other techniques will have similar lists of potential problems, biases and errors, so examining those accompanying aerial surveys should suffice to warn investigators of the potential problems with any technique.

Aerial surveys have two major components: reconnaissance and estimation surveys. Before initiating either, first the potential sources of error should be identified.

In connection with the reconnaissance surveys the following aspects should be considered:
1) have all the pupping/moulting patches been found,
2) will they remain discrete during the survey (weather and ice conditions must be taken into account), and
3) when will the optimum time in the pupping/moulting period occur to best estimate total population.

Next the survey method should be chosen. This will be dependent on the extent of coverage required and the nature of the group to be surveyed. Aspects to be considered include:
1) photographic or visual surveys, or both,
2) counting adults or pups, or both,
3) surveying whelping areas or moulting areas,
4) covering total areas or subsample,
5) groundtruthing and calibration procedures.

In commencing the estimation surveys, problems to be considered include:
1) can all the concentrations, heavy and sparse, be covered; and if so, at what intensity ?
2) is the amount of overlap betweeen transects and/or photos accounted for to ensure that double counting does not occur in reading the photographs ?
3) is ice drift accounted for to ensure that redundancy does not occur if transects or whelping patches merge ?
4) is the number of seals hidden from view accounted for ?
5) is the number of seals in the water (and thus not available for counting) estimated ?
6) is the number of pups/females which have left , or not yet arrived on the breeding/moulting grounds accounted for ?
7) can mixed species or sexes be distinguished ?

With photographic or video surveys, consideration should especially be given to:
1) are all the pups/adults on each photograph identified correctly ?
2) are all the pups/adults in the photographs detected ?
3) if adults are counted, is the sex being correctly assigned from the photograph ?

With visual surveys, the following points should be adressed:
1) is the flying altitude and speed low enough to ensure correct counts ?
2) is the strip width small enough to ensure that all seals are counted ?
3) will observer fatigue cause errors in counting ?
4) will the transcribing system ensure accurate recording ?
5) does the transect remains a known, constant width ?

With thermal imagery, special problems include:
1) will existing weather conditions influence results ?
2) is the resolution sufficient to distinguish between closely spaced animals ?

Having identified the potential errors, then it is important to measure the extent and direction of these errors, i.e. to estimate the degree to which these problems will influence the final estimate of production.

A few examples of such an estimation of errors were illustrated by the following presentation:

W.G. Warren: Correcting aerial survey estimates of harp and hooded seals.

Abstract: Two sources of error are considered:
1. Failure of the reader of the photograph to detect all pups that are present or the misidentification of lumps of ice or shadows as pups;
2. Because of the length of time over which births take place, not all of the pups may be on the ice at the time of the survey.

1) The dual camera system, as described in Doc. 4, permits the first of these source of error to be examined. Although the photographs were taken at different time intervals and at different scales, there are places where the frames overlap, i.e. cover the same area at the same time. The counts on such pairs were compared and any differences explained to obtain what was regarded as the "correct" number for each matched pair.

Since plots of the correct count against the observed count gave no suggestion of non-linearity, correcting the recorded number, x_i, to the actual number of pups, y_i, was done using a linear regression $y_i = a + bx_i$. Separate regressions were constructed for each of the three readers. All photographs read by a reader were then corrected by using the regression equation made for that reader. Transect totals were then obtained by adding the corrected photograph counts, multiplied by a weighting factor if coverage was not continuous (see Doc. 4 for greater detail).

The uncertainty associated with this correction was estimated by a resampling procedure (the "bootstrap" -

Efron 1979, 1981). Specifically, the data used for each regression are resampled, with replacement, a large number of times to create a distribution of corrected totals for each transect. The variance of this distribution provides a measure of the uncertainty for the corresponding corrected transect total, from which the "measurement" component of the variance of the total population estimate can be calculated. It turns out that this component is small, generally less than 10 % of the total uncertainty.

2) The method of adjusting for not all pups being on the ice at the time of the survey was developed by R.A. Myers and initially presented for hooded seals in a paper by Bowen et al. 1987. A revised version applied to harp seals appeared in a paper by Myers and Bowen, 1989.

It is assumed that the rate at which pups are born can be expressed as a continuous function of time, $m_1(t)$, and that pups pass through a series of identifiable stages. It is also assumed that the probability of a seal passing to the next stage depends only on the time spent in the previous stage (a semi-Markov process). The parameter, $\phi_j(\tau)$, thus represents the probability of moving into stage j from stage j-1 when the length of time spent in stage j-1 is τ. The rate, $m_j(t)$, at which individuals enter stage j at time t can then be calculated if it is assumed that the mortality of pups is very small, and hence the number of pups in stage j at time t, $n_j(t,\theta)$, where θ represents all of the parameters ϕ_1, ϕ_2 ... $m_1(t)$ with the addition of, if necessary, a parameter for the proportion of the final-stage pups in the water at time t.

If S_{ij} represents observed number and P_{ij} the true proportion of pups in stage j at time t_i, then

$$P_{ij} = \frac{n_j(t_i,\theta)}{\Sigma_j\, n_j(t_i,\theta)}$$

where the "likelihood", $L(\theta)$, is proportional to the production of the P_{ij} raised to the power S_{ij} (The approach can be easily extended if the S_{ij} are obtained as cluster samples).

One would like to estimate the parameters by finding the values that maximise the likelihood, but this is not possible. Instead the q_i are estimated from independant data of known age pups. For this, the ϕ_1, ϕ_2, ... are assumed to have a known distributional form e.g. exponential, gamma, Weibull, log-logistic; likewise for the $M_1(t)$. Note that $M_1(t)$ can be estimated only up to a constant factor. Thus from the proportions in each stage estimated at a succession of dates it is possible to estimate, for a particular patch, the proportion of pups available to the survey at any given date and thus "correct" the survey data obtained on that date.

The use of maximum likelihood estimation method allow us to estimate the variance or uncertainty associated with the correction factor. If the survey is well timed, i.e. carried out when the maximum number of pups is available, the correction for harp seals in particular would be small and so would be its uncertainty. This component is only a small part of the total uncertainty, the largest part of which stems from the usual sampling variance associated with incomplete coverage of the population (see Doc. 4). For hooded seals, the correction and its variance will generally be larger but still contribute a relatively small part to the overall uncertainty.

Potential problems:
i) The distributional forms used are, to date, arbitrary and selected so as to give the best fit to the data. It would seem desirable to have a single form, theoretically related to the birthing process, that is appropriate to all places and years.
ii) Estimation could be simplified if the length of time in a stage duration were stable from year to year. The duration reported by Myers and Bowen (1989) appears, however, to be approximately 70 % of that for the 1990 survey (Doc. 4). Reasons for this are not known but can be speculated.
iii) In the 1990 survey there was some suggestion that the distribution of births over time was bimodal, so that none of the usually assumed distributional forms would be appropriate. Reasons for this are also not known.

References:
Bowen, W.D.; Myers, R.A. and Hay, K. 1987. Abundance estimation of a dispersed, dynamic population: Hooded seals (Cystophora cristata) in the Northwest Atlantic. Can. J. Fish. Aquat. Sci. 44: 282-295);

Efron, B. 1979. Computing and theory of statistics: Thinking the unthinkable. SIAM (Soc. Ind. Appl.Math.) Rev 21: 460-480;

Efron, B. 1981. Non parametric standard errors and confidence intervals. Can. J. Stat. 9: 139-172.

Myers, R.A. and Bowen, W.D. 1989. Estimating bias in aerial surveys of harp seal production. J. Wildl. Managem. 53: 361-372.

There was some discussion concerning the extent of the influence of these types of error on the total uncertainty, and the conditions under which the sampling error would be large.

7. ALTERNATIVE METHODS OF ASSESSING SEAL ABUNDANCE

Although a number of papers were presented on alternative methods, such as mark-recapture, line transects and moulting patch surveys, the discussions concentrated on aerial surveys. Some comments on other methods were however discussed.

a) Moulting patch surveys have also been conducted in the White Sea. Historical information is extensive on the White Sea, and hence Russian researchers believe that the changes in age and sex composition during the season is well understood and hence can be corrected to provide information on age composition. Further, during the moulting season harp seals of all ages and both sexes are highly concentrated in localized areas. Aerial surveys are conducted routinely on moulting patches and concurrent biological sampling occurs for age composition analysis. It is believed that these surveys and the age composition data provide a good estimate of population size and age and sex composition.

Questions were raised pertaining to the representativeness of the samples to estimate population size and age/sex composition, that is whether random sampling do occur. Since animals arrive and depart throughout the moulting period, it would be difficult to obtain random sampling. Canadian researchers noted that off Newfoundland, as elsewhere, the males and juveniles appear first and depart earlier than adult females. Thus age and sex composition varies throughout the season, and this variation is not constant from year to year.

The Norwegian research in the Greenland Sea suggests that the moulting season is long and segregation by age and sex occurs. Further, it is difficult to survey the moulting patches since the seals react to the aircraft at low altitudes by entering the water more than they do in the breeding season. It would then be difficult to obtain reliable population estimates or age composition data.

In conclusion, it was noted that, in theory, obtaining population estimates and age composition data from the moulting patches is possible. In practise, however, the changing age and sex composition in these patches during the moulting season and between years may make obtaining representative samples difficult.

b) Mark-recapture assessment. It was suggested that mark-recapture techniques, while still important for distributional information, is no longer a viable method for harp and hood seal population estimation in the Northwest Atlantic. This is because most of the assumptions associated with that model will be violated, some seriously. Also, the recapture of marks was via the seal hunt which has been reduced.

c) Line transects. On the conduct of line transect surveys, as for surveys in general, several aspects should be considered. They include,

1. if the line transects are parallel, should they then be randomly or systematically located ?
2. should they be stratified by some criterion ?
3. should the transect coverage be complete or periodic ?
4. will the probability of sighting and classifying the seals along the transect be affected (related to terrain, weather, etc.) ?

5. how will the new survey procedures be calibrated with historical techniques ?

The discussion on the line transect method dealt mainly with whale surveys. During ship or aerial surveys, seal sightings have been collected. Similar to whales, the probability of sighting seals appears to be related to the size of the herd. The estimation methods designed for clustered samples should be considered.

8. FUTURE WORK - PROPOSALS AND RECOMMENDATIONS

1. It is **recommended** that efforts be continued to improve the biological, technical and analytical aspects of estimation surveys,

2. The present workshop has spent considerable time discussing the potential errors in conducting estimation surveys, thus it is **recommended** that all these points (Sect. 6, p. 14-15) be considered in planning, conducting, analysing and reporting the results of such surveys.

3. Further, it is **recommended** that the direction and extent of potential errors should be estimated whenever possible using the appropriate statistical techniques, and that these statistical evaluations be considered by groups using these data in population estimation.

4. The current workshop was successful in adressing most of the aims set out in its terms of reference but did not have enough time or expertise to deal with statistical aspects in detail. It was therefore **suggested** that a future workshop be held to examine the statistical aspects of the estimation survey methods.

9. PUBLICATION OF THE REPORT

It was agreed that the report should include the abstracts of the presentations, the ensuing discussions, and the recommendations. The report would be made available to the relevant ICES/NAFO bodies.

It is **recommended** that the report of the present workshop be published by ICES (or NAFO).

10. ADOPTION OF THE REPORT

A hand-written draft report, up to and including Section 7 (Agenda item 9), was adopted during the meeting. The recommendations put forward under agenda items 10 and 11 (Section 8-9) were agreed by consensus. The chairman was charged to edit the report and distribute it for final adoption by mail.

Appendix 1

AGENDA

1. Opening by the convenors (Yu.K. Timoshenko/G.B. Stenson).

2. Election of Chairman and Rapporteur(s).

3. Adoption of Agenda.

4. Review of documents.

5. Review of current survey methods for harp and hooded seals:

   Presentations:

   5.1 Yu.K. Timoshenko: Aerial photographic surveys in the White Sea.

   5.2 V.I. Chernook: Russian surveys in the Greenland Sea.

   5.3 N. Øien: Norwegian surveys in the Greenland Sea.

   5.4 G.B. Stenson: Methods of estimating pup production of harp and hooded seals in the N.W. Atlantic.

   Discussion.

6. Review of survey methods for other seal species:

   Presentations:

   6.1 W.T. Stobo: Validation of aerial photographic estimates of grey seals on Sable Island, Canada.

   6.2 M.O. Hammill: Estimating pup production of ice breeding grey seals in the Gulf of St. Lawrence, Canada.

   6.3 E. A. Petrov: Methods and techniques of assessing Baikal seals.

   6.4 O. Svetocheva: Methods of ringed seal stock assessment.

   Discussion.

7. New technology or methods in aerial surveys:

   Presentations:

   7.1 G.B. Stenson: The use of ultra-violet imagery for assessing pup production.

   7.2 V.I. Chernook: The use of thermal imagery for assessing harp seal abundance & Application of complex automated systems during aerial surveys.

   7.3 N. Øien: The use of video cameras during seal surveys.

   Discussion.

8. Methods of analysis of aerial surveys:

   General discussion: Sources of errors in conducting surveys.

   Presentation: W.G. Warren: Correcting aerial survey estimates of harp and hooded seals.

9. Alternative methods of assessing seal abundance:

   a) Moulting patch surveys;

   b) Line transects:

   c) Other.

10. Future work, proposals and recommendations.

11. Publication of report or proceedings of the workshop.

12. Other business.

13. Adoption of the report.

Appendix 2

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Appendix 3

LIST OF DOCUMENTS

Doc. 1. Timoshenko, Yu. K.: Aerial photographic survey at harp seal puppy rookeries in the White Sea in 1980-1991.

Doc. 2. Chernook, V.I.; Alayev, S.G.; Bogomolov, V.Yu; Timoshenko, Yu. K.: Automated system for aerial survey and photography of commercial accumulations of sea mammals.

Doc. 3. Potelov, V.A.; Chernook, V.I.: Assessment of harp and hooded seal stock of the Greenland Sea.

Doc. 4. Stenson, G.B.; Ni, I-H.; Myers, R.A.; Hammill, M.O.; Warren, W.G.; Kingsley, M.C.S.: Aerial survey estimates of pup production of harp seal (Phoca groenlandica) in the Gulf of St. Lawrence and off Newfoundland during March, 1990. CAFSAC Res. Doc. 91/83.

Doc. 5. Kuznetsov, N.V.; Chernook V.I.: Assessment of new born seal abundance when conduction seal survey.

Doc. 6. Estep, K.W.; MacIntyre, F.; Noji, T.T.; Stensholt, B.; Øritsland, T.: Seal abundance and habitat conditions assessed from aerial photography and video analysis (submitted for publication in ICES Journal of Marine Sciences, Sept. 1992).

Doc. 7. Borkin, I.V.; Chernook, V.I., Ponomarev, Ya.I.; Bogomolov, V.Yu.: Results of the air survey on sea birds in the Barents Sea in autumn 1991 (5th Soviet-Norwegian Symposium, Interrelation between fish populations in the Barents Sea).

Doc. 8. Chernook, V.I.; Myasnikov, V.; Potelov, V.: Application of complex UHF surveys for monitoring of areas of sea mammals' dwelling.

Doc. 9. Ni, I-H.; Stenson, G.B.; Ripley, H.: Evaluation of ultra-violet photography in the detection of seals.

Doc. 10. Stobo, W.T.: Calibration of aerial survey estimates of grey seal pup production on Sable Island.

Doc. 11. Hammill, M.O.; Stenson, G.B.; Myers, R.A.: Hooded seal pup production in the Gulf of St. Lawrence.

Doc. 12. Hammill, M.O.; Myers, R.A.; Stenson, G.B. and Stobo, W.T.: Grey seal (Halichoerus grypus) pup production in the Gulf of St. Lawrence.