# COUNTING AND MEASURING BALEEN AND VENTRAL GROOVES OF WHALES

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### ABSTRACT

Counts and measurements of baleen and ventral grooves are important in taxonomic descriptions of whale species and in feeding studies. Standard methods are needed. This paper proposes a standard system.

Definitions are given for: baleen plate, hair, bristle, tip and base of a plate, filter area of the whole baleen, ventral groove.

Measurement methods are given for: counting baleen, measuring length, width and thickness of a plate, density of spacing and average gap between plates, diameter of bristles, filter area of the whole baleen, counting ventral grooves.

## INTRODUCTION

Counts and measurements of the baleen and ventral grooves of mysticete whales have frequently formed part of the systematic description of species. However, the criteria and methods used to obtain these data have seldom been defined.

It is desirable that the methods be standardised. The standard methods adopted must be simple, easy to repeat with accuracy and meaningful in terms of the function of the structures concerned. This paper suggests such standard methods and is based on the opinions of the experts listed in the acknowledgements section.

Definitions and measurements covered in this paper are:

*Baleen*

| | |
|---|---|
| definitions: | Baleen |
| | Baleen series |
| | Side of baleen |
| | Main baleen plate |
| | Minor baleen plate |
| | Hair |
| | Bristle |
| | Tip of baleen plate |
| | Base of baleen plate |
| measurements: | Counts of baleen |
| | Length of baleen series |
| | Length and width of a baleen plate |

Length and width of a baleen lamina
Thickness of a plate
Average density of spacing of plates
Average gap between plates
Diameter of bristles
Length of bristles
Density of spacing of bristles

*Baleen Filter Area*
definition:        Filter area of the baleen
measurement:       Filter area of the baleen

*Ventral Grooves*
measurements:   Number of ventral grooves
Length of ventral grooves
Mandible to umbilicus length
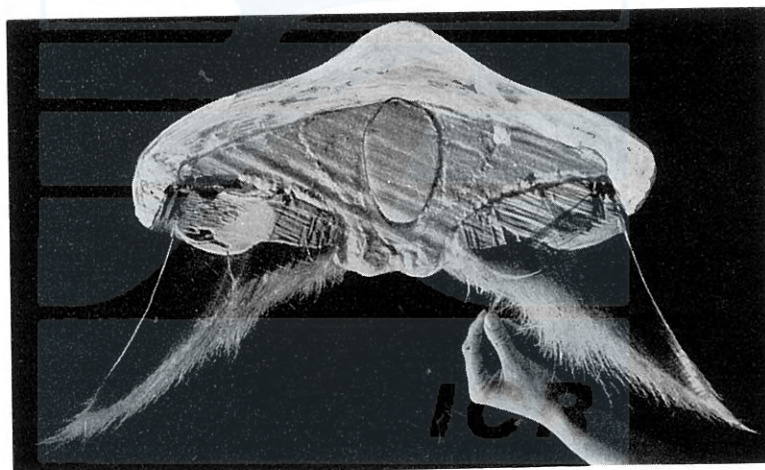Degree of separation of end of ventral grooves from umbilicus.



Fig. 1.   Section of upper jaw of a sei whale showing position of the baleen.

## SUGGESTED DEFINITIONS AND METHODS OF MEASUREMENT

*Baleen*
Definitions

   *Baleen* is the general name given to the keratinous filter attached to the upper jaw of mysticete whales (Figs. 1–9).   On each side of the upper jaw is one *baleen series* or *side of baleen*.   Each baleen series is composed of a series of *baleen laminae*. Each baleen lamina consists of a large *main baleen plate* on the outer side; several *minor baleen plates* and at the inner or lingual edge, some *hairs*.   At the extreme front

and rear ends of a baleen series the baleen laminae are composed only of hairs. The shape of the main baleen plates of various species of whale are shown in Fig. 3.

*Plates* are components of the baleen series which at gum level have a width three or more times their thickness. *Hairs* are components of the baleen series arising directly from the gum whose width at gum level is less than three times their thickness (Figs. 4, 6 and 7).

The filter fibres that form a fringe on the side of each plate are called inner *bristles*, not hairs.

*Tip of baleen plate* (Figs. 3, 8) is the most distal part of the solid plate that be detected and beyond which the plate ceases to exist but is divided into many bristles. The *base of the baleen plate* is where it emerges from the gum.

*Counts of baleen* are made on the outside of the baleen series at gum level. Ideally, the number of structures on both sides of the jaw are counted and the average calculated. Three categories of structures could possibly be counted:
• the hairs at the front of the series.
• the baleen plates in the middle of the series (defined as in *Baleen*).
• the hairs at the back of the series.
These all correspond with baleen laminae. However, the hairs at the back of the series are too small to count accurately and in Right and Gray whales the anterior hairs are also too small to count accurately. Thus the baleen structures best counted are as follows                                                                    ‘

Rorqual and Humpback whales: the hairs at the front of the series plus the baleen plates

Right and Gray whales: the baleen plates only.

In Rorqual and Humpback whales the count is started at the first hair at the front of the baleen series. To discover the centre position at the front of the snout an imaginary line is drawn from the tip of the snout backwards between the two pits of Jacobsens organ until it reaches the baleen hairs (Fig. 6, top left). On a flensing deck this line can be marked on the gum with a knife.

*Length of baleen series* (Fig. 2) is the distance between the bases of the most anterior and the most posterior elements of the series measured in a straight line parallel to the axis of the body.

*Lengths and widths of baleen plates and laminae* are shown in Fig. 8. The two points between which measurement is made are given in each case following:
• *Length of main baleen plate, straight* (AB) is the distance from the tip of the plate to the insertion of the plate into the gum at the outer edge, measured in a straight line.
• *Length of main baleen plate, curved* (AC) is the distance from the tip of the plate to the the insertion in the gum of the base of the same fibres which make up the tip of the plate, measured along the growth axis of the fibres.
• *Length inner edge of baleen lamina, straight* (AD) is the distance from the base of the innermost hair of the lamina to the tip of the main plate of the lamina, measured in a straight line.
• *Length inner edge of baleen lamina, curved* (AD curved) is same as above, but measured along the curve connecting the bases of the bristles of the baleen plates and hairs.

• *Width of baleen plate* (BE) is the distance between the base of the outer edge and the base of the inner edge of the plate, measured along the surface of the plate.
• *Width of baleen lamina* (BD) is the distance between the base of the outer edge of the main plate and the base of the innermost hair of the same lamina measured along the curve of the lamina base.

*Thickness of a plate* is the thickness measured in the mid area of the plate (point X in Fig. 8) *i.e.* approximately half way between the base and tip of the plate and half way between the outer and inner edge of the plate.

*Density of spacing of plates* is the distance between the centres of the edges of adjacent plates, measured at the outer edges of the plates midway along their lengths.

*Gap between plates* is the width of the gap separating a plate from its neighbour, though which water passes when the whale is feeding, measured at the outer edges of the plates midway along their lengths.

These two characters are useful in studies of the mechanics of filtering, thus are chiefly important when they relate to the central section of the baleen series which does most of the filtering. To achieve this aim, the average spacing and average gap between plates should be determined by taking measurements of the 100 longest baleen plates in the centre of the baleen series. The measurements should be made on the outer edge of the baleen series at a level approximately half way along the length of the plates (Fig. 2 top). The measurements should be made on baleen in situ in the whale's mouth, because the spacing becomes altered as soon as the baleen is cut free from the gum.

$$\text{average spacing} = \frac{\text{length of that section of the baleen series made up by the 100 longest plates}}{100}$$

average gap = average spacing—average thickness of the 100 longest plates

*Diameter of a bristle* is the diameter of a bristle at its base, measured with a micrometer screw or microscope with eye-piece scale. To measure the average diameter of bristles of a plate the following procedure is recommended:
  1.  Cut all the bristles from three sites exactly 1 cm wide on the plate edge, one at the top, one at the middle and one at the bottom of the plate (Fig. 5).
  2.  Measure the diameter of the base of each bristle.
  3.  Calculate the average diameter of the bristles.

*Length of a bristle* is the distance from base to tip of a bristle. The value is only reliable if measured on a fresh whale, since bristles commonly break short in preserved plates. The average length of bristles on a plate can be determined by the same method as the average diameter of bristles.

*Density of spacing of bristles* is the average number of bristles arising per 1 cm of baleen plate edge, and is determined by counting the number of bristles cut off three 1 cm sites as described above.

In whales whose baleen plates are worn down at the tip, as often occurs, the measurements of bristles at the 1 cm site on the plate tip should be discounted.

*Filter Area*

The filter area of the baleen series is the area of the inner surface of the combined left and right baleen series in the mouth of the whale. Since the inner surface of the baleen is somewhat curved (Fig. 1) it is difficult to measure the filter surface accurately. For convenience, it is suggested that a ' *standard filter area* ', in which it is supposed that the inner surface is flat, be used for preliminary work. The ' *true filter area* ' is the true total filter area of the baleen, taking into account all the various curves of the surface of the baleen.

Measurement of standard filter area can be done in several ways. To collect data on many whales at a busy shore station or factory ship, a photographic method is recommended (Fig. 9). The sequence of operations is as follows:
• species, length and sex (and/or platform number) of the whale are written on a black slate in chalk.
• whale details slate and a 1 meter or 50 cm rule are placed against the baleen series of the whale.
• a photograph of the baleen series is taken in which the camera is positioned as near as possible at right angles to the inner surface of the baleen, opposite to the centre of the baleen series. This can be achieved either by the photographer standing on a box or the whale's head being partially turned on edge using a winch.
• the film negative is projected onto graph paper and the outline of the baleen series and rule are traced. The outer border of the baleen series is drawn over the tips of the baleen plates, as defined earlier.
• the standard filter area is calculated by counting the number of graph paper squares covered by the traced outline of the baleen.

The standard filter area is a function of the length of the baleen series and of the length of the longest plate (straight length, as previously defined) of the series:

standard filter area=series length × length of longest plate × k

From a good series of data the average value of k for each species of whale can be calculated. When k is known, the standard filter area of any specimen can be calculated from a knowledge of the length in meters of the baleen series and the straight outer edge length of the longest plate only—provided that in different sized individuals and in different stocks the overall shape of the filter area remains similar.

A few preliminary measurements I made suggest that in *Balaenoptera* species the value of k is 2.2–2.7, in *Eubalaena* about 1.5.

The ultimate aim of filter studies will be to determine such fundamentals as
• body weight supported per $m^2$ of filter surface.
• weight of food collected per minute per $m^2$ of filter surface.
and then to discuss the relative efficiency of the mouth anatomy and method of feeding in different whale species and the problems a whale experiences when trying to capture the different species of food organisms (krill, copepods, anchovy, mackerel etc.). Investigations on how the expandable grooved throat of rorquals is used to increase filtering efficiency will be of particular interest.

*Ventral Grooves*

*Number of ventral grooves* is the number of grooves on the ventral surface of the whale counted at the level of the point where the grooves extend highest up the side of the body *i.e.* where the number of grooves is maximum.   This point is located between the eye and the flipper of the whale (Figs. 10 and 12 top).   Since a whale on a flensing deck lies on its side, it is usually impossible to count all the grooves.   The best method to obtain the value is to look at the tip of the lower jaw and there locate the mid-ventral groove, follow it back to the level of the count, count the grooves round to the highest groove and double the result.   The median groove can also be identified by locating the umbilicus and following forward the middle groove.

*Length of ventral grooves* (VGL) is the distance from the tip of the lower jaw to the posterior end of the longest ventral groove or grooves, measured in a straight line parallel to the axis of the whale's body, but excluding the mid-ventral groove that in some species runs between the umbilicus and genital aperture.   (It is useless to measure the length of the ventral grooves along the curve of the throat because the throat of a dead whale is always unnaturally dilated).

*Mandible to umbilicus length* (MUL) is the distance from the tip of the lower jaw to the centre of the umbilicus measured in a straight line parallel to the axis of the whale's body.

*Degree of separation of end of ventral grooves from umbilicus*

$$\text{degree of separation} = \left( \frac{\text{MUL} - \text{VGL}}{\text{total body length}} \right) \times 100$$

In species where the ventral grooves terminate posterior to the umbilicus, the value will be negative.

## DISCUSSION

It is hoped that the standard methods for defining, counting and measuring ventral grooves and baleen plates of whalebone whales given in this paper may be adopted by future workers.

Much work remains to be done to document the range of values of these characters in different species, populations, ages and sizes of whales and to determine coversion factors that will enable such new data to be compared with published figures.

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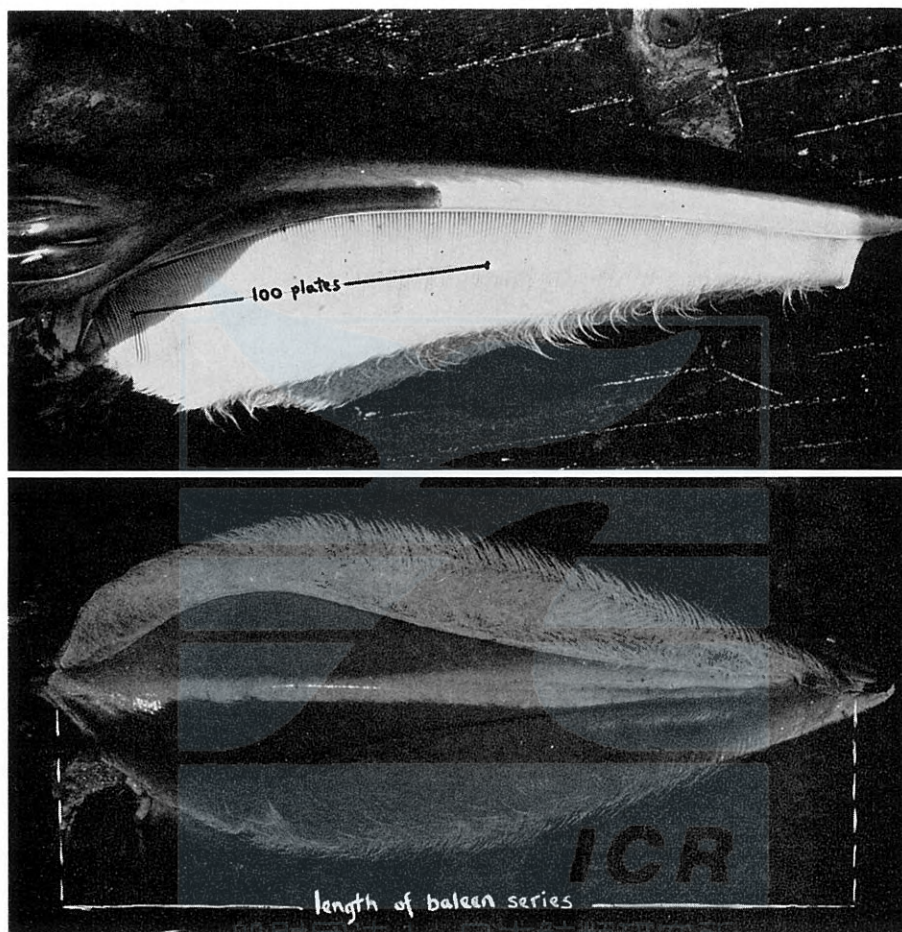


Fig. 2.   Top:   Side view of baleen of a minke whale.   Line marks position of
the 100 longest plates measured when determining average density of spacing
of plates and average gap between plates.
Bottom:   Underside view of baleen of a minke whale showing how to measure
the length of the baleen series.
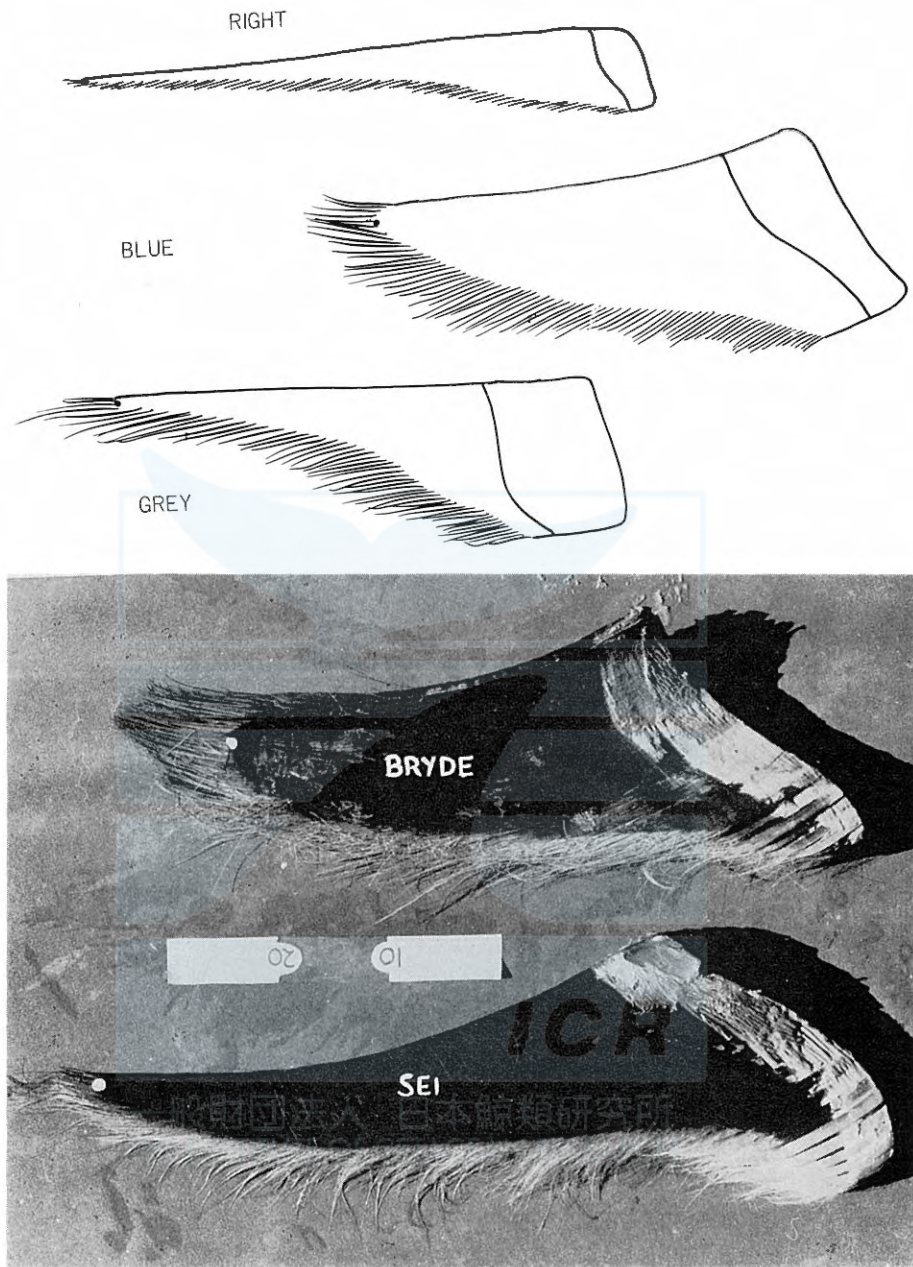
Fig. 3.　Baleen plates of various species of whales.　The tip of each plate is marked with a dot.

Fig. 4. Top: Diagram explaining difference between hairs and plates. Plates are defined as baleen elements which at gum level have a width three or more times their thickness.

Bottom: Front part of baleen of a sei whale showing the arc of hairs at the front of the mouth which joins the two sides of the baleen.
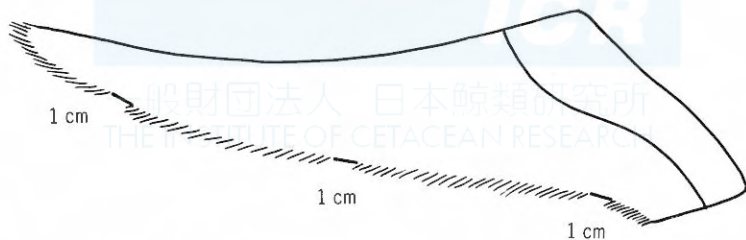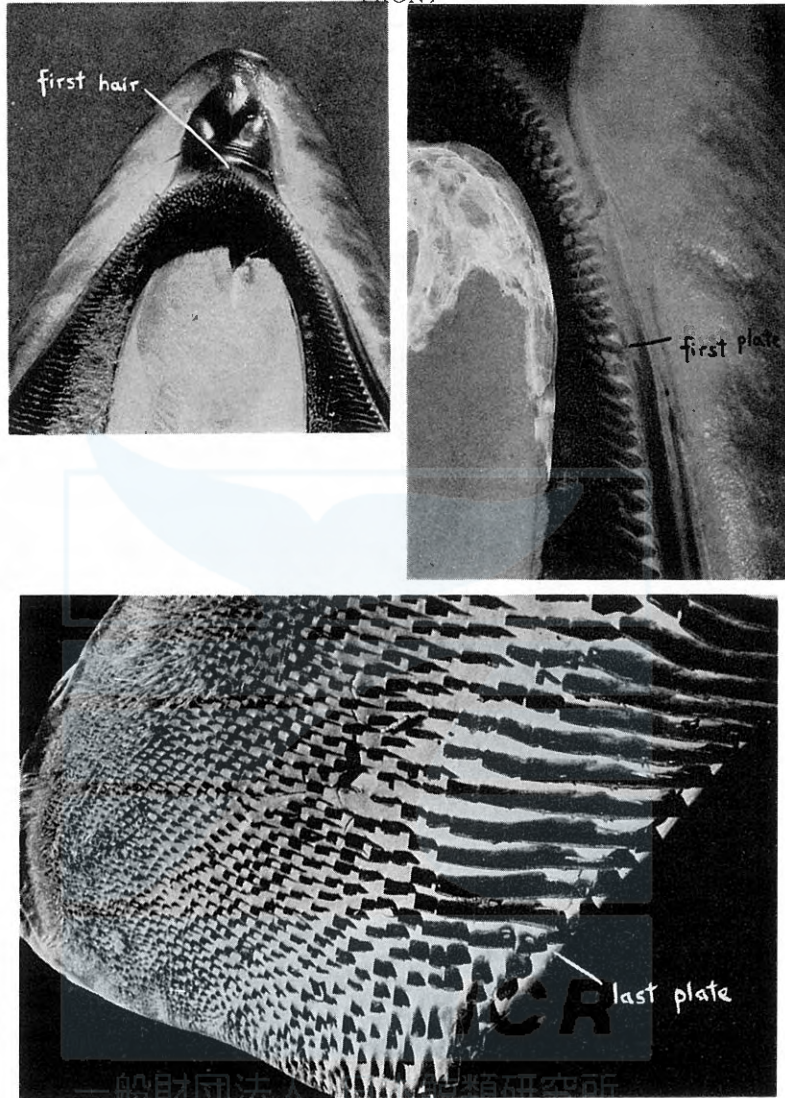


Fig. 5. Diagram of a baleen plate showing positions of the three sites from which bristles are cut off to measure their thickness and length.

FRONT



BACK

Fig. 6. Baleen of a sei whale cut off at gum level.
   Top left:   Front of mouth.
   Note the dense bunch of hairs at the apex of the jaw.   Presumably these help
prevent fish and krill escaping forwards when the feeding whale closes its mouth.
   Top right:   Detail of front left part of series
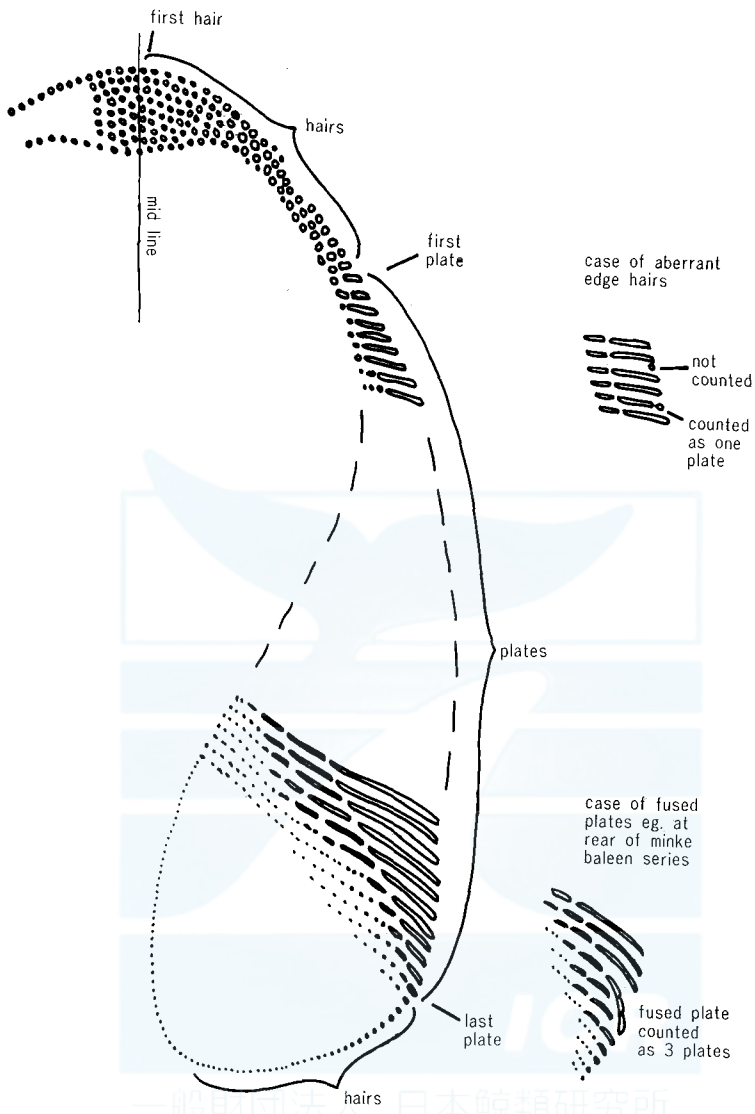   Bottom:   Left rear part of series.

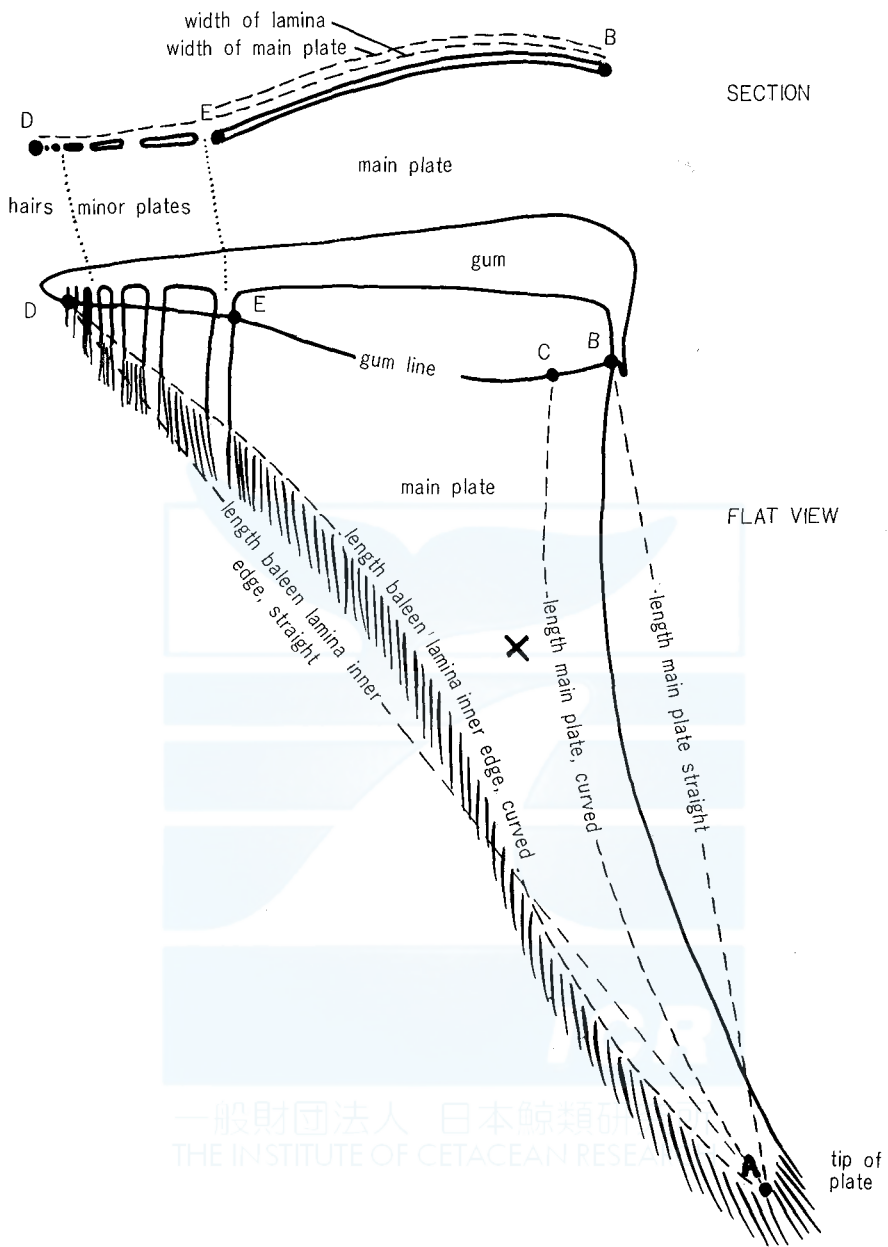Fig. 7.  Diagram of baleen series of a generalised rorqual showing how to count hairs and plates.

Fig. 8.   Diagram of a baleen lamina of a generalised rorqual showing where to
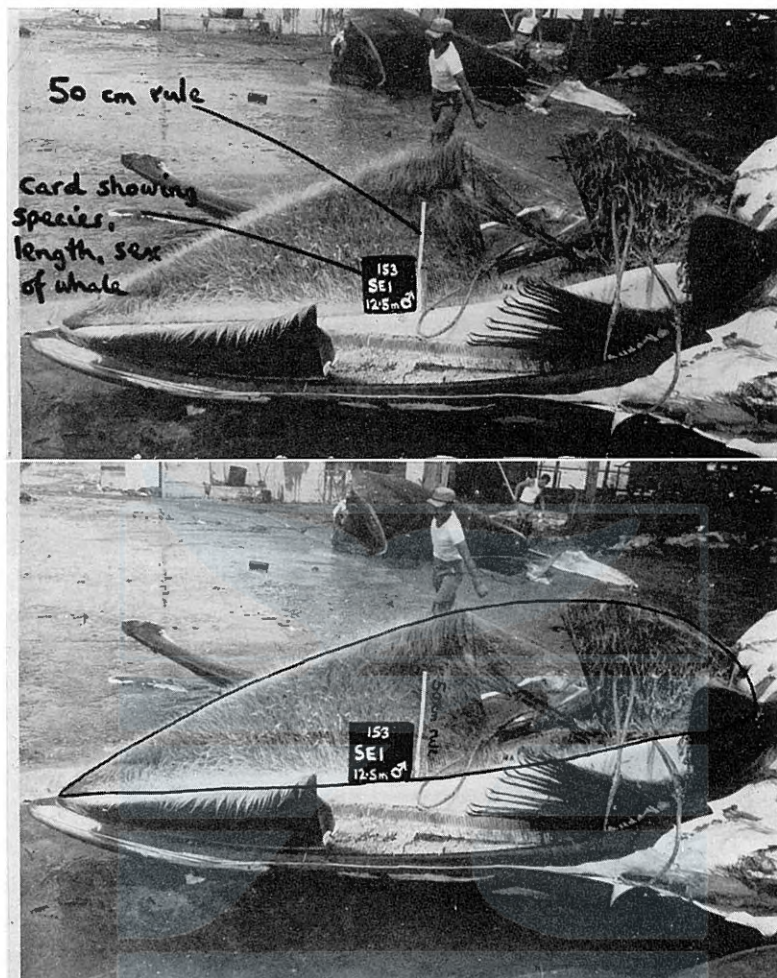take various measurements.

Fig. 9.   Method of measuring filter area of a sei whale's baleen series.
Top:   Photo of baleen is taken with camera positioned opposite to the centre
and at 90° to the inner surface of the baleen series.
Bottom:   Projected onto graph paper, the outline of the baleen is traced along
the tips of the plates and the area calculated by counting the number of graph
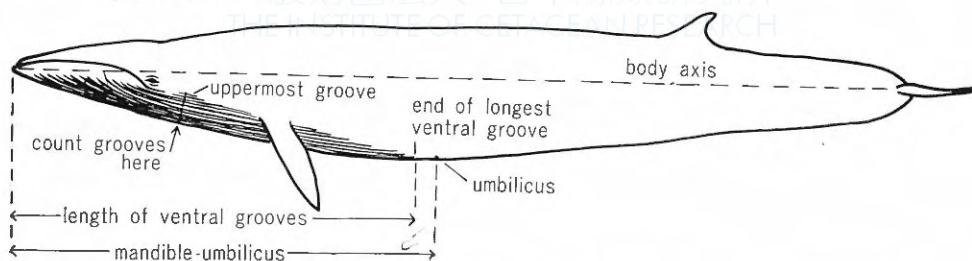paper squares covered.

Fig. 10.   Diagram of body of a sei whale showing where to count and measure
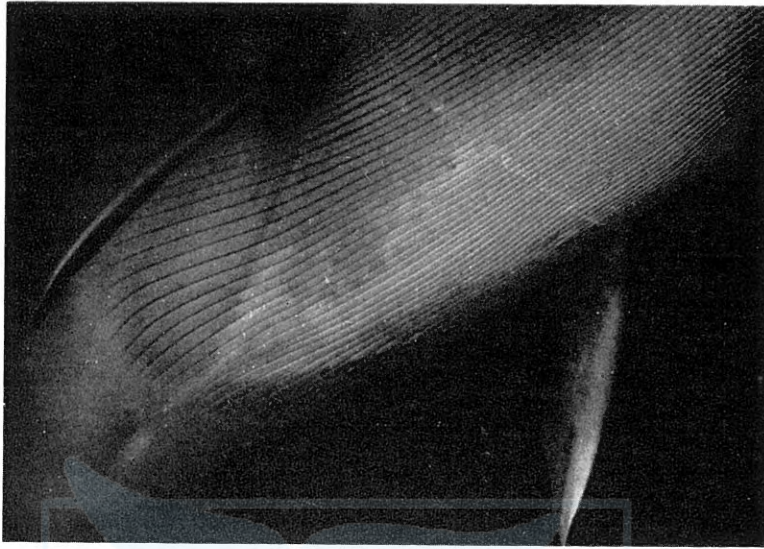the ventral grooves.

Fig. 11.   Live sei whale seen from underwater showing ventral grooves.



top groove

count grooves here

line of count

front

count 4 grooves

umbilicus centre

end of longest
ventral groove

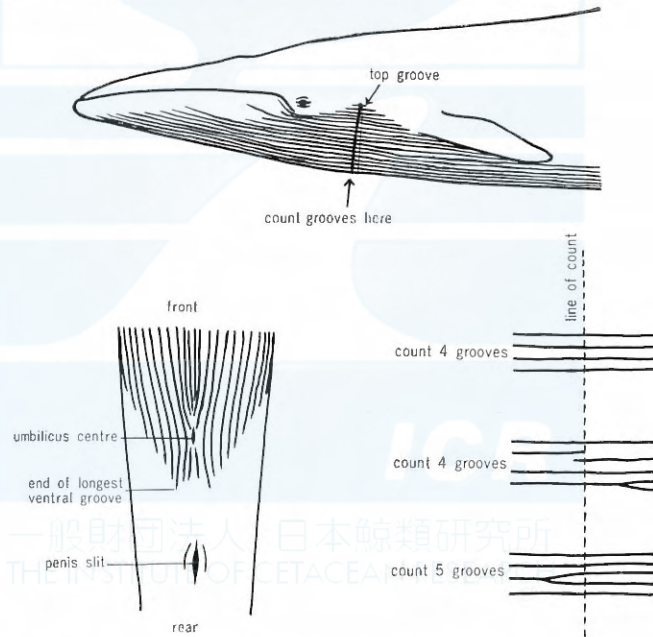count 4 grooves

penis slit

count 5 grooves

rear

Fig. 12.   Top:   Head of blue whale showing where to count the ventral grooves.
The ventral grooves of rorquals extend highest up the side of the body in blue
whales.   In minke whales the uppermost groove is level with the angle of the
jaw.   Note the groove—free area below the rear part of the jaw bone.
Bottom left:   Diagram showing how to count ventral grooves in cases where the
grooves terminate or fork near the line of count.
Bottom right:   Arrangement of ventral grooves of a   male   blue   whale   in the
region of the umbilicus.