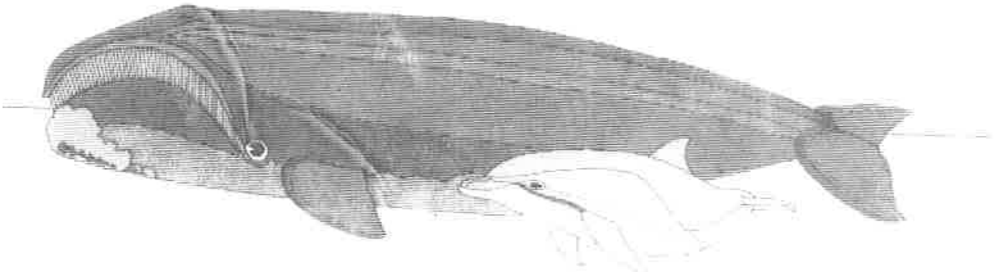
EUROPEAN RESEARCH ON CETACEANS - 7

PROCEEDINGS OF THE SEVENTH ANNUAL CONFERENCE
OF THE EUROPEAN CETACEAN SOCIETY,
INVERNESS, SCOTLAND
18-21 FEBRUARY 1993



EDITOR : P.G.H. EVANS

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INTRODUCTION

The sixth annual conference of the European Cetacean Society was held in Inverness, North-east Scotland between 18th and 21st February 1993. It was attended by over 200 persons from nineteen countries. The Council of the ECS are very grateful to Paul Thompson and his team of assistants recruited from Aberdeen University, for organising a most successful conference.

The proceedings that follow are abstracts of the talks and posters presented at the conference. As for previous proceedings, the contributions have been edited only to improve clarity and to maintain a uniformity of presentation. No external refereeing has taken place and much of the material presented here it is hoped will eventually be formally published in greater detail in scientific journals. As the number of contributions increases from year to year, the total size of the proceedings becomes larger. We feel that this has now reached about the maximum size that is both economic and manageable. It is important that these proceedings are not seen as an alternative way of publishing results without the constraint of peer review. For those reasons, in future the maximum length accepted for an individual contribution will be reduced to two pages of text and two pages of figures/tables.

I have tried to arrange the abstracts broadly by subject, and for this reason, the invited key note lectures are slotted into appropriate spots through the volume. I would like to take this opportunity to give warm thanks to the invited speakers, some of whom came a great distance to address the society: Andy Read and Randy Wells from North America, and Bill Amos from England

Finally, I should like to thank Kate Grellier for the unenviable task of typing out these proceedings.

Peter G.H. Evans

HUMPBACK WHALE (*Megaptera novaeangliae*) SOCIAL ORGANISATION IN WEST GREENLAND AS INDICATED BY GROUP SIZES.

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INTRODUCTION Humpback whales are migrating baleen whales. The winter is spent in lower latitudes calving and mating, and the summer is spent in northern latitudes feeding. Humpbacks at the feeding grounds are thought to be discrete populations of individuals showing site fidelity to each feeding ground. This study is conducted on the feeding ground off West Greenland. Humpback whales are frequently seen in groups on both feeding grounds and breeding grounds and it is my hypothesis that the frequency, and composition of these groups can give us an idea of humpback whale social organisation.

METHODS A group consists of two or more animals swimming or resting side by side with a distance between individuals of no more than three body lengths (approx. 45 m.). The members of the group co-ordinate diving, surfacing, and speed and direction of movement.

Data have been collected by the Greenland Fisheries Research Institute (GFI) in the summers of 1988-91, a total of 77 days. The area covered includes the fishing banks off West Greenland from 61°30'N to 66°30'N. For photo-identification purposes, pictures were taken of the ventral surface of the tail flukes of the humpback whales encountered. Along with the photographs, date and duration of observations, position, and group size was noted. The photo-identification data gave information about the composition of each group photographed.

RESULTS AND DISCUSSION 522 sightings of whales were made, including 1,012 individuals. 778 individuals were photographed and 419 IDs were made. This should be considered in relation to a 1989-90 humpback whale population estimate for West Greenland of 400-450 individuals (Finn Larsen, GFI, pers. comm.).

Frequency of group sizes were plotted for each year separately (Fig. 1). There were two significantly different distributions for 1988 and 1989-91 ($p << 0.05$ that the two distributions are the same in a G-test). These two distributions of group size frequencies have also been found in other studies (e.g. Whitehead, 1983) but there is currently no explanation for the difference in distributions. A possible explanation with reference to this particular feeding ground is that the humpback whale food may have been differently distributed in 1988 and 1989-91.

For animal species like the humpback whale that form casual groups (as opposed to demographic groups), a comparison can be made between the observed distributions of group sizes and theoretical ones (Cohen, 1971). A zero-truncated Poisson distribution should occur if grouping is due to non-social factors; this could perhaps be expected for the humpback whales since they spend most of the time on the feeding grounds foraging (the size of the food patches could be the determinant of humpback whale group sizes). A zero-truncated binomial distribution should occur if one or more group sizes are attractive per se; in this case, grouping would be dependent to some degree on social factors.

Neither of the two theoretical observations match the observed distributions for any of the four years (Table 1). Thus, the size of humpback whale groups is not determined by food patch size alone. The observed distributions differ from the binomial distribution in a uniform way, which emphasises the point made when comparing the two distributions, namely that one or more group sizes are favoured over others for this whale species. It is evident that for all four years, groups of two are over-represented at the expense of all other group sizes in the observed distributions. Thus although the observed distributions do not match the binomial distribution, it can be concluded that this one group size is indeed preferred to others by the whales.

Since the whales are feeding most of the time at the feeding grounds, the preference for duos could be related to feeding. The duos may be stable constellations of animals that had a long history of cooperation on finding, catching, and consuming food, thus enhancing the success of each individual. The photographic material from the four years has been tested for such constellations. No constellations were observed to last longer than 48 hours (Fig. 2). It is important to note that these cruises were designed for making mark-recapture population estimates and that data yielded are not ideal for investigations of social organisation. The method used can give information on constellations lasting years and perhaps weeks but is not suited for gathering information about short-lived constellations. However, there is a preference for duos and this preference does not seem to be related to the formation of long-lasting constellations.

Perhaps the preference for this group size may not be related to feeding. When comparing the humpback whale with the sympatric fin whale (*Balaenoptera physalus*), at least in some regions, (Whitehead & Carlson, 1988), the preference for duos becomes even more obvious. The fin whale group size distribution appears to correspond much more to a Poisson distribution with no obvious preference for a particular group size. Thus although the fin whale is in so many ways like the humpback whale, it does not have the same pattern in group size preference.

Supplementary explanations to those connected with feeding are needed to account for humpback whale grouping. The humpback whales, like many other cetaceans, may travel in herds, and grouping could be a way of maintaining herd identity by at least sporadic contact with the other members. A social system of this kind is known for several terrestrial species. The Australian whiptail wallabies (*Macropus parryi*) (Kaufmann, 1974) live in herds and have a distribution of group sizes very similar to that of humpback whales, preferring duos. A humpback whale herd could consist of the entire feeding ground population or smaller parts of this. It will, however, take much more data and a more directed effort before one can make reliable statements about humpback whale social organisation on the feeding grounds and in general.

REFERENCES

Cohen, J.E. 1971. *Casual groups of monkeys and men*. Harvard University Press, Cambridge, Massachusetts, xiii + 175 pp.

Kaufmann, J.H. 1974. The ecology and evolution of social organization in the kangoroo family (Macropodidae). Amer Zool., 14(1): 51-62.

Whitehead, H. 1983. Structure and stability of humpback whale groups off Newfoundland. Can. J. Zool., 61(6): 1391-1397.

Whitehead, H. & Carlson, C. 1988. Social behavior of feeding finback whales off Newfoundland: Comparisons with sympatric humpback whales. Can. J. Zool., 66(1):217-221.

Table 1 Comparison of observed and theoretical (see text) frequency distributions of humpback whale group sizes in West Greenland 1988-91. Probability values at the bottom of each year relate to the probability that the observed distributions match the theoretical distributions

1988

Group size	Observed	Poisson dist.	Binomialdist.
1	71	73,287	71,351
2	37	32,517	35,229
3–7	10	12,195	11,419
Probability		30 %	60 %

1989

Group size	Observed	Poisson dist.	Binomialdist.
1	45	64,307	56,555
2	83	56,350	62,471
3	34	32,918	38,336
4	8	14,432	14,116
5–7	5	6,901	3,520
Probability		<< 0,05 %	0,5 %

1990

Group size	Observed	Poisson dist.	Binomial dist.
1	41	53,495	47,638
2	64	44,933	49,867
3	23	25,161	28,999
4	8	10,567	10,119
5–7	3	4,783	2,376
Probability		0,5 – 1,0 %	5 – 10 %

1991

Group size	Observed	Poisson dist.	Binomial dist.
1	33	38,329	34,992
2	39	29,103	32,302
3	13	14,732	16,566
4–7	5	7,814	6,140
Probability		5 – 10 %	20 – 30 %

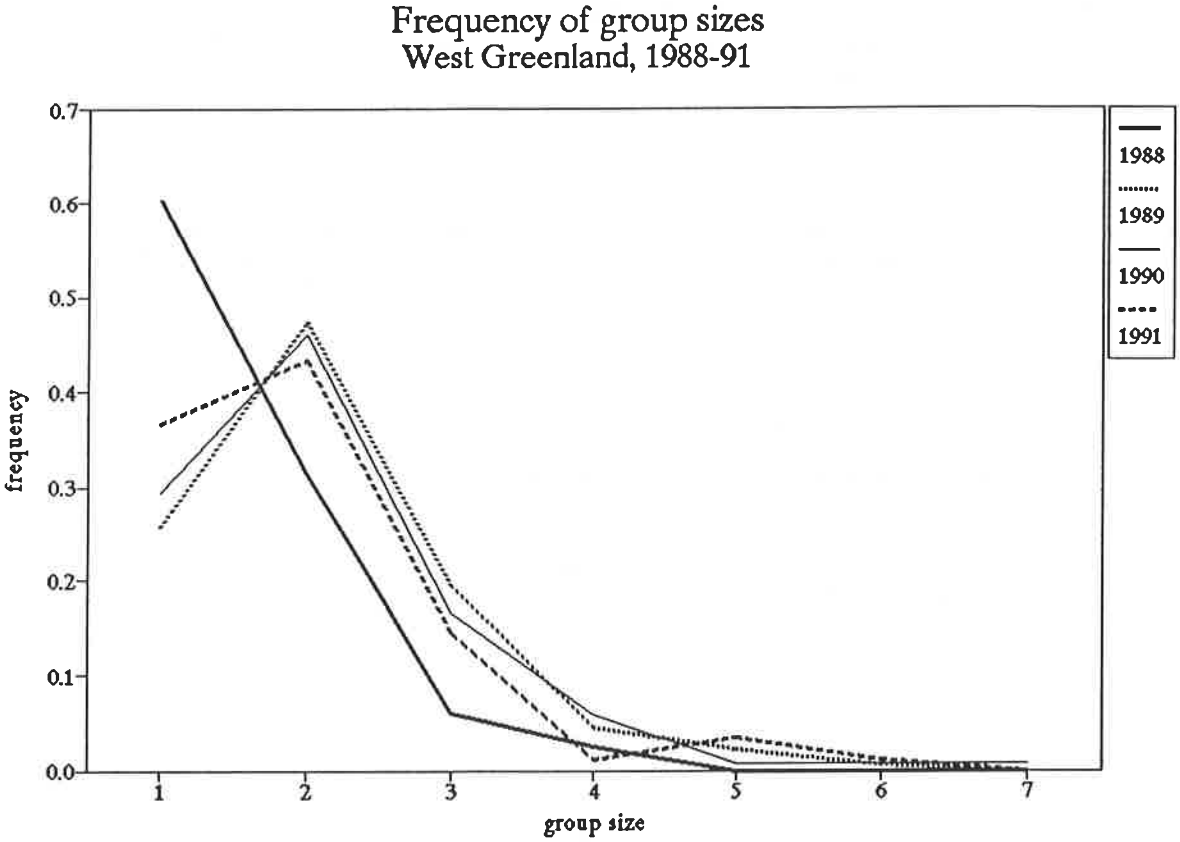

Fig. 1, Frequency distribution of group sizes, West Greenland 1988–91. Note the two different distributions: One for 1988 and one for 1989–91. See text.

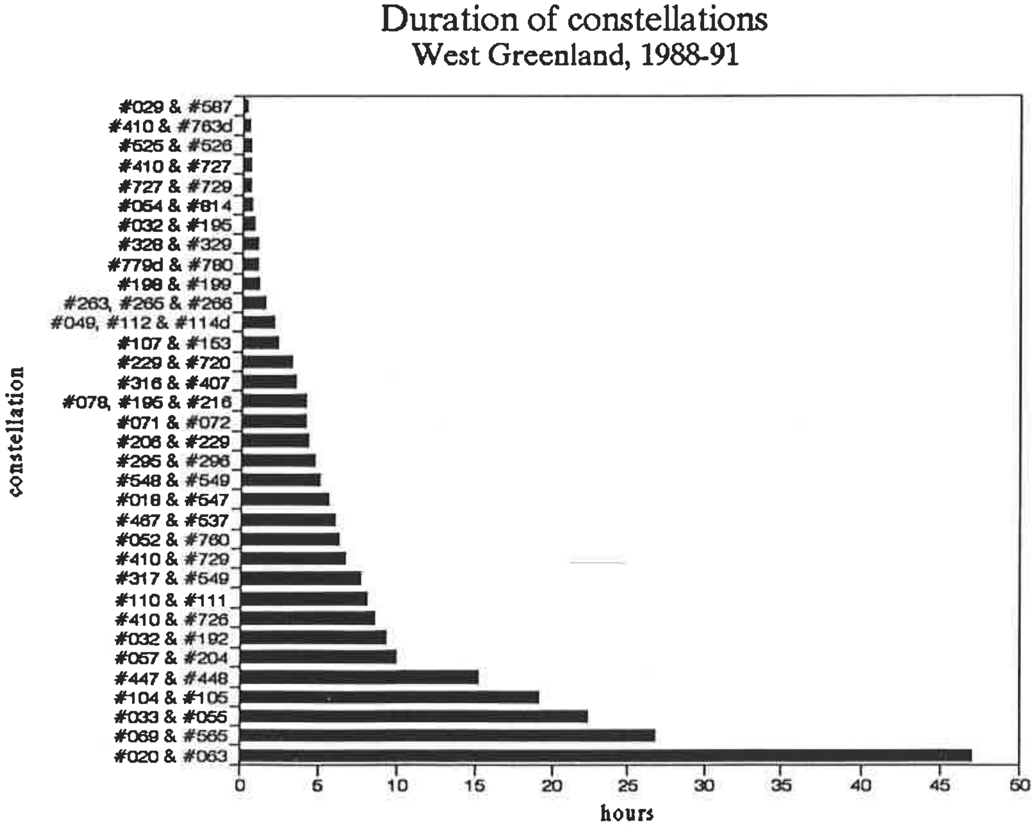

Fig. 2, Duration of constellations, West Greenland 1988–91. The numbers on the constellations–axis indicate the ID–numbers of the individuals in the constellation.

THE SOCIAL STRUCTURE OF PILOT WHALE PODS IN THE FAROE ISLANDS : GENETIC INSIGHTS

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The long-finned pilot whale swims in large social groups, or pods, often numbering over 100 individuals. Pods are extremely cohesive, to the extent that mass-strandings are frequent and the animals may be herded readily by boats. Material from complete pods taken in the Faroese drive fishery, have provided an unprecedented opportunity to look at relationships between individuals within a pod. Both DNA fingerprinting and single locus analysis have been used to deduce several features of pod structure.

In a detailed study of two pods, evidence was found that all individuals were related to the dominant female line within the pod. Even the adult males appear to have remained with their mothers. Limited emigratiom from the pod cannot be ruled out. Mating is thus likely to occur as a recoprocal event, with males from one pod fertilising females from another and vice versa. This gives weight to the indication that groups of related males fertilise foetal cohorts. The implications are that outbreeding is maximised through an incest taboo, but that males gain further inclusive fitness by staying at home to help raise the large number of whales that have been born to their female relatives.

PILOT WHALE PODS: MATING GROUPS OR FEEDING GROUPS?

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INTRODUCTION Living in groups entails a variety of costs and benefits (Maynard Smith, 1979). The currency of this trade-off is reproductive success, the representation of an individual's genes in future generations (Clutton-Brock, 1986). Reproductive success for males is primarily maximised by obtaining the greatest number of matings, while females are best served by ensuring the survival of the finite number of offspring they can produce in a lifetime (Trivers, 1985). Of course, both sexes also need to obtain resources and avoid predation to ensure their highest quality survival to maximise their reproductive success. However, the majority of mammalian societies appear to be composed of mating groups: males and females come together to increase mating opportunities. In polygynous mammals, males attempt to control access to a group of females, fighting with other males and soliciting female choice. These broad principles of evolutionary biology have been proposed to explain the prime motivating factors behind the formation of mammalian social groups.

Recent studies of the genetics of long-finned pilot whales have shown that breeding males do not maintain residence in their mates' social groups (Amos *et al.*, 1991). Instead, males and females are related within a group. This suggests that the social groups of pilot whales, which are known to be highly cohesive through their propensity to strand, are not mating groups. A similar hypothesis has been proposed for the social groups of the closely related killer whale (*Orcinus orca*) where males live with their mothers' social group and mating appears to occur between separate social groups (Heimlich-Boran & Heimlich-Boran, ms). We have been conducting a study of the short-finned pilot whale (*Globicephala macrorhynchus*), in the Canary Islands (28°N, 17°W) since 1989, in order to examine this potentially unique social system in more detail.

METHODS AND RESULTS Field work was conducted off Tenerife Island in a 22 month study from October 1989 through July 1991. Two hundred and seventy-seven pilot whale groups were located on 155 of 200 days of effort and were observed for 543 hours. Four hundred and ninety-five individual animals were identified from photographs of naturally-occurring marks and scars on the dorsal fin and back. Individuals were classified into five age and sex categories: adult male, female with calf (or mother), unknown, juvenile and calf. These categories were based on relative differences in overall body size and sexually-dimorphic characters such as the development of the melon (the fatty organ on the forehead), and the position and shape of the dorsal fin. Information on consistent associations between adults and young was used to define mothers. The category of unknowns could be composed of either adult females without calves or adolescent males which had not attained a larger body size than adult females (approximately 8-11 years old).

The number of sighting days per animal ranged from one (N = 186) to 28 (N = 1) and averaged 5.27 ± 5.96 (mean ± SD, N = 495). Two classes of whales were defined: residents and visitors. Residents were all animals seen more than once and all animals seen once in the company of animals seen more than once. Visitors were defined as animals seen only once and not in the company of animals seen more than once. There were 15 distinct visitor groups, totalling 107 identified animals and 16 clean-finned immatures. Visitors could either be pilot whales resident to other regions simply exploring the Tenerife area or could possibly be true transients, continually roaming over wide areas, as has been shown for *Orcinus*.

Associations between individuals in the 277 groups were tallied to calculate indices of association. The index used was the Ratio Association Index (RAI), which standardises observations of the number of times a pair of animals was seen together as a proportion of the combined total number of times either individual was sighted (Ginsburg & Young, 1992). A matrix of the resulting indices for all possible pairs of the 245 adult whales seen more than once was analysed for clusters representing social groups. Hierarchical, agglomerative clustering methods were applied using an Unweighted Pair-Group Average algorithm.

Thirty-one clusters were identified on the basis of all clusters linked at distance coefficients less than 3.0. These clusters were termed "pods". Eighteen of the pods were linked at distance coefficients between 3.0 and 4.0 into eight higher level clusters; these pods were termed "linked" pods. The 31 resident pods and 15 visitor pods varied in size from 2 to 33 and averaged 12.2 ± 1.3 (mean ± SE). The average age/sex composition (all values mean ± SE) of all pods was 2.5 ± 0.2 males, 2.2 ± 0.4 females with calves, 4.7 ± 0.5 unknowns, and 3.0 ± 0.5 immatures. All pods with immatures (32 of 46: 70%) were considered as productive pods while the remainder (14 pods or 30%) were considered as non-productive pods. Four of these productive pods (12.5%) had no adult males in association with them, suggesting that males do not maintain continuous contact with breeding females, as has been shown by the genetic studies of long-finned pilot whales. These pods of females and calves could represent nursery pods. Two of the non-productive pods (14%) were composed solely of adult males (totalling two and six), while the remainder were composed of a mixture of adult males and unknowns. If the unknown animals were adolescent males, this could be an indication of adult male segregation into separate pods. Productive pods were significantly larger than non-productive pods (15.5 ± 1.4 vs. 4.6 ± 0.6, $t = 4.99$, $P < 0.0001$). Comparisons of resident and visitor pods showed there were no significant differences in the numbers of productive and non-productive pods ($X^2 = 2.77$, $0.10 > P > 0.05$, $df = 1$), but resident pods could be characterised by their larger size (14.1 ± 1.6 vs. 8.2 ± 1.5, mean ± SE, Mann-Whitney $U = 327.5$, $Z = 2.23$, $P < 0.05$) and lower percentages of males than visitor pods.

Analyses of associations between animals from different age, sex and pod classes were only conducted on resident pod groups due to the limited observations of visitor pods. Only 8.1% of the 27,999 possible between-pod pairs were recorded in associations between the 245 resident adults seen on more than one day, compared to 80.5% of the possible between-linked-pods pairs and 96.7% of the 1,167 possible within-pod pairs. Comparisons of the levels of these associations showed that within-pod pair association indices were significantly higher than those of between-pod pairs (mean association: 0.39 vs. 0.07) and between-linked-pod pairs (mean association: 0.18; Kruskal-Wallis $H = 2419.5$, $P < 0.001$), emphasising that although members of different pods did associate, the associations were infrequent.

Associations between members of the 5 age/sex classes also showed significant differences (all associations, Kruskal-Wallis $H = 19.57$, $P < 0.005$), and these differences varied depending on the pod membership of the two individuals (within-pod associations, Kruskal-Wallis $H = 21.38$, $P < 0.001$; between-linked-pod associations, Kruskal-Wallis $H = 23.29$, $P < 0.001$; between-pod associations, Kruskal-Wallis $H = 22.99$, $P < 0.001$; Fig. 1). Within pods, all associations within and between males and unknowns (e.g. male:male, male:unknown and unknown:unknown pairs) were significantly higher than all associations in which females and calves were members (Scheffe's F-test for multiple comparisons). The highest ranked associations were between adult males, indicating that male:male pairs had the most consistent relationships. In light of the high degree of relatedness documented between mature males in long-finned pilot whale pods, these relationships could also be kin-based. Of all mother pair associations of females with calves, the highest were with other mothers, while associations with males and unknowns ranked lower. The overall ranking of associations was slightly different for pairs from different pods. Associations were still significantly higher within and between pairs of males and unknowns when compared to the associations of mothers. However, within the mother associations, pairs of mothers were the lowest ranked of all associations, opposite to the case for within-pod associations. Thus mothers from one pod did not associate frequently with mothers from other pods. When linked pods travelled together, the highest ranking associations of mothers were with adult males. In fact, multiple comparison tests indicated that these associations were not significantly different from associations between adult males (male:mother = 0.189± 0.011 vs. male:male = 0.198± 0.021; Scheffe's F = 0.037, P >0.05). If mothers are considered as the reproductive females, their association with adult males from linked pods could support a hypothesis that mating may occur outside of the pods. If mating was occurring within pods, higher association might be expected between adult males and females with calves.

There were also seasonal variations in the sizes of pilot whale groups. It was hypothesised that group size might vary according to variation in food availability or to mating opportunities. Group sizes of identifiable whales from both years were pooled into two half year periods: summer (April-September) and winter (October-March). Groups were significantly larger during summer (8.5 ± 0.5, n = 171) than during winter (6.9 ± 0.5, n = 106; Mann-Whitney U = 10375.5, Z = 2.03, P <0.05). Also, the number of different pods (represented by one or more individuals from any given pod) documented in these groups was significantly greater in summer (1.77 ± .09, N = 171) when compared to winter (1.48 ± 0.08, N = 106; Mann-Whitney U = 10182.5, Z = 1.96, P <0.05). This suggests that pods are more likely to group up during the summer. May and July have been proposed as the peak conception dates for short-finned pilot whales off Japan and long-finned pilot whales off the Faeroe Islands, respectively. If gestation is 12 months, this would also correspond to the peak month of newborn calf observations in June. Thus, the hypothesis that mating might occur when pods join together would be supported by these findings.

DISCUSSION Our observations of pilot whale pod structure and the high level of association between "linked" pods are consistent with the hypothesis that pods are not isolated breeding groups. Seasonal mating could be occurring between males and females from different pods, with individuals subsequently returning to travel with their permanent pods. If this is correct, then the lack of potential mating associations between individuals from the same pod may suggest a form of inbreeding avoidance, which would be expected if individuals within a pod were related. This is very different from the "typical polygynous mammalian society, where one sex or the other emigrates from their natal pod to form breeding groups with unrelated individuals of the opposite sex.

If pilot whale pods are not mating groups, then what is their function? They are known to be highly cohesive; so much so that strong social bonds may be partly responsible for their common mass strandings. We propose that these pods are primarily feeding groups. Their cohesive nature is essential in order to function as a cooperative unit in locating and capturing dispersed food resources in the deep ocean. Benefits of remaining with kin may include an increased likelihood of altruistic and cooperative acts amongst group members.

REFERENCES

Amos, B., Barrett, J. and Dover, G.A. 1991. Breeding behaviour of pilot whales revealed by DNA fingerprinting. Heredity, 67: 49-55.

Clutton-Brock, T.H. (ed.) 1988. *Reproductive Success.* Univ. of Chicago Press.

Ginsburg, J.R. and Young, T.P. 1992. Measuring association between individuals or groups in behavioural studies. Anim. Behav., 44: 377-379.

Maynard Smith, J. 1979. Game theory and the evolution of behaviour. Proc R. Soc. Lond., B.205: 475-488.

Trivers, R. 1985. *Social Evolution.* Benjamin/Cummings, Menlo Park, CA. 462 pp.

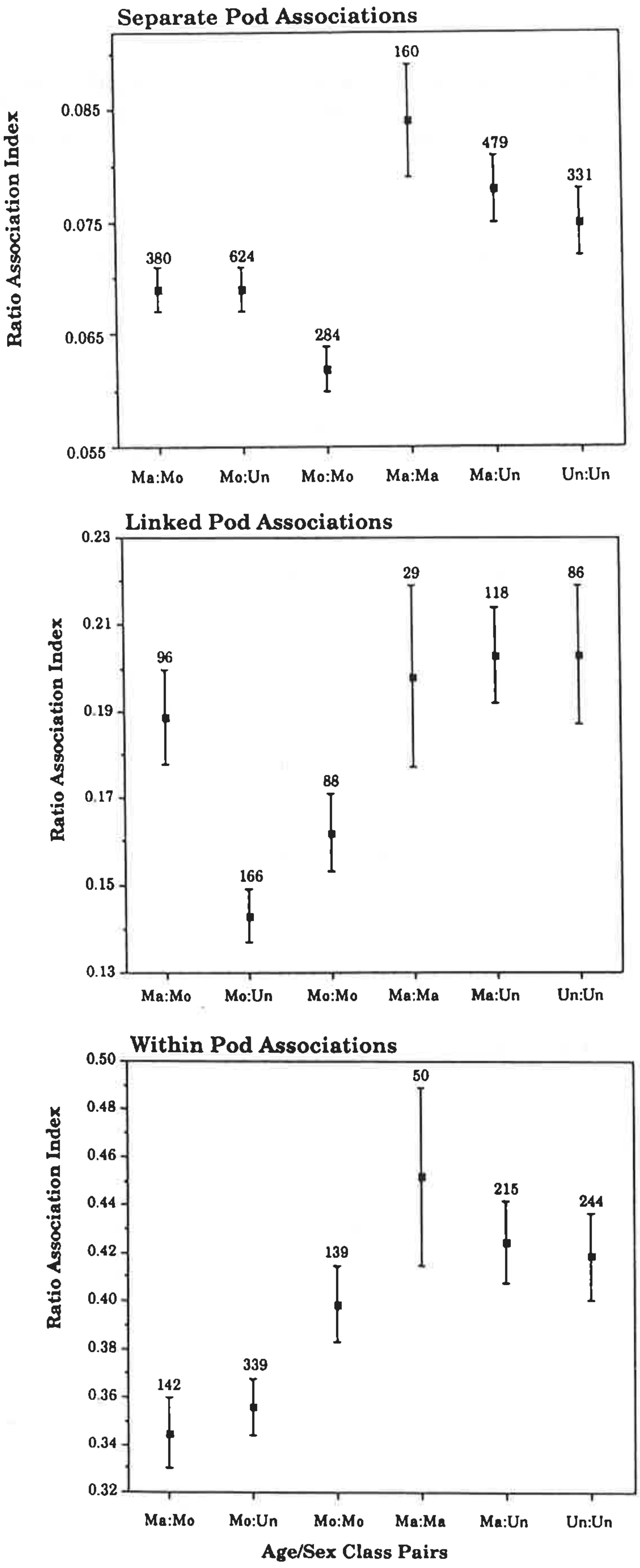

Fig.1 Average association indices (mean ± SE) for pair associations (excluding immatures) between members of separate pods, linked pods and between whales within a pod grouped by the age and sex classes of each of the members of the pair. Age/Sex class abbreviations are for adult males (Ma), mothers (Mo) and unknowns (Un). Sample sizes for each bar indicate the total number of pairs for each age/sex class combination.

THE CORRELATION BETWEEN THE SOCIAL STRUCTURE OF LONG-FINNED PILOT WHALES *(Globicephala melas)* AND ITS RELATIONSHIP TO THE DRIVE HUNT IN THE FAROE ISLANDS

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INTRODUCTION Pilot whales (*Globicephala spp*) are gregarious species living in pods with strong social ties and consequently a highly developed degree of social cohesion. Behavioural and genetic work on both long-finned (*Globicephala melas*) and short-finned pilot whales (*G. macrorhynchus*) in the North Atlantic show pods that are matrilineal, based qpon an extended family core, centred around one breeding adult female and her immature offspring (Amos, *et al.*, 1991; Amos, this vol.; Heimlich-Boran & Heimlich-Boran, this vol.). Although pilot whales are polygynous, studies have shown that the males in a pod are genetically unrelated to the young in the same pod. Reproductively active males migrate between pods and may form small bachelor pods, and mating appears to be a reciprocal event between adults in different pods (Amos *et al.*, 1991, Amos, this vol., Bloch, 1992). The number of animals in pods range from less than ten to super-pods which can contain more than 1,000 whales (Evans, 1987).

Historical drive hunts of pilot whales have occurred in several countries including Canada and the UK, although they are now limited to two countries: Japan and the Faroe Islands. This report concentrates on data obtained from the Faroese drive hunt. Long-finned pilot whales have been killed in the Faroe Islands for at least 400 years.

The drive in the Faroe Islands can be divided into three distinct phases:
(1) the pre-drive phase, when the pod is sighted and 'herded' together by boats;
(2) the middle-drive phase, when the whales are driven from the sighting area into the designated bay;
(3) the pre-beaching phase, where the intention is to drive the whales onto the designated beach before killing them.

MATERIALS AND METHODS Data on pod size and drive distances, and the number of whales killed are taken from records from the Faroese Museum of Natural History (Bloch, 1988). Data on drive times are taken from 43 drives that occured from July 1986 and June 1988 (Bloch, 1988; Bloch *et al.*, 1990).

A hunt was documented at Funningsfjord, Faroe Islands on July 2nd, 1992. The pod in this hunt contained approximately 100 animals of which 87 were killed. Video film was shot at the drive, using video Hi-8 film from a number of locations and using a number of different cameramen. This film was analysed and the behaviour of the whales during the driving phase and the post-beaching phase of the hunt recorded, with emphasis on gathering information on the social cohesion of the pod, during the three phases. This is compared with documented reports on pilot whale behaviour and social structures.

RESULTS Figure 1 shows the average pod size of pilot whales for the period 1970-1992. This ranges from 65.5 in 1991 to 262.5 in 1973.

The second phase of the hunt consists of driving the pod into the designated bay. The time and distances for the drive can vary with maxima of 30 kilometres and 10 hours 45 minutes recorded respectively (Bloch, 1988; Bloch *et al.*, 1990). Drive times for 35 hunts taken from a 23 month period (July 1986 to May 1988), showed a range from 15 mins to 4 hrs 11 mins, and a mean of 1 hr 32 mins (Bloch *et al.*, 1990).

Figure 2 shows the relationship for 31 drives between the time taken to drive a pod and the distance of the drive. The most common distance for drives that lasted under one hour, was less than 10 km (50%); this was followed by distances of 10-20 km (23%). The most common time period for drives between 10-20 km was 1-2 hours (38.5%). Figure 3 shows the relationship for 35 drives between the number of whales in the pod and the time taken to drive the pod. Most pods containing between one and fifty whales took less than two hours, although exceptions do occur - one pod of 35 whales took over four hours to drive.

Analysis of video footage shows that none of the pod split away from the main pod during the drive phase along Funningsfjord. The direction of the pod was also constant in this phase. The diving pattern of the animals is regular and coordinated, with groups of animals diving simultaneously and in a synchronous fashion. Data gathered over a three-minute period from four of these groups as they were driven along Funningsfjord showed a mean of 7.5 whales sounding together. Data from other drives shows up to 16 whales sounding synchronously. The arc of the dive is semi-circular with the fin of the whale cutting below the water surface.

Analysis of data from hunts between July 1986 and May 1988 shows that in 31 out of the 42 drives during this period, the entire pod was killed (Faroese Museum of Natural History, 1986, 1987; Bloch, 1988).

Once the animals are driven into the designated bay, there is an attempt to beach the pod in preparation for killing. Immediately prior to the beaching of the pod, the coordinated pattern of the whales' dives alter. The speed of the pod increases, and the arc of the whales' dives become shallower, with the fin of the whale rarely going below the surface.

The drive at Funningsfjord in July 1992 consisted of at least five separate drives on the pod. The animals that were not beached on the first attempt re-grouped in the middle of the bay. Analysis of the animals' movements here reveals a complete breakdown in social formation. The whales lose their fixed directional mode, swimming in large circles. The dives of the animals are not co-ordinated, and several whales swim counter clockwise to the rest of the group. Dive patterns continue to be shallow, with little communal sounding.

At this time there is an increase in two behaviours: spyhopping and lob-tailing (a whale standing on its head in the water with its tail in the air). In the two-minute period immediately following the first whales turning away from the shore after the initial drive, there were 14 instances of tail lobbing recorded. During the middle drive phase, no instances of these behaviours were recorded.

Approximately half an hour after the first drive, it was possible for the boats to re-group the remaining whales and start driving them towards the shore again. During this second driving phase, the whales' diving behaviour returned to a 'deep diving' pattern accompanied by whales breathing in unison. This behaviour occurred until the whales reached the shore, when the pod's social cohesion broke down again. This was similar to the pattern of behaviour documented in the initial drive.

DISCUSSION In the Faroe Islands, once a pod is sighted, the sheriff calls together a flotilla of boats which collects the pod and drives it into one of the 27 designated whaling bays with licensed beaches.

The data show little apparent relationship between the duration of the drive and the distance, or between the duration of the drive and the number of animals being driven. Although there were slightly more drives under 10 km which lasted less than one hour, one drive of two kilometres took over two hours, the same time as a drive of 18 km (Bloch, 1988). This is because other variables influence the duration of the drive. These include climatic and tidal conditions during the drive and time of original sighting. These variables are all additional and unrelated to actual distances involved and numbers of whales in the pod.

The data do show a positive relationship between the social cohesion of the pod and the small number of whales lost from the pod during the drive. The data also show a high level of social cohesion during the drive, including communal sounding, dive patterns and directional mobility. This would facilitate the drive and thus reduce the amount of time taken. Boats located behind the whales are able to dictate the direction of the pod, as this is guided by the lead pilot whale and helped by the cohesive nature of the pod. It would appear that the pattern of social cohesion is maintained and underlined by the coordinated movement of the animals.

Pilot whales are a very communicative species, employing a wide range of auditory and ultrasonic communication (Taruski, 1979; Heimlich-Boran, 1992). Studies on pilot whales in the wild reveal an ability to recognise individual signature calls and mental states (Taruski, 1979).

The coordinated formation of dives and their direction during the middle part of the drive is probably aided by this well developed communication system. An increase in vocalisations has been recorded from other drive hunts in Newfoundland, showing that intra-pod communication is continuous when the pod is being driven (Taruski, 1979).

The second part of the drive hunt is the period immediately prior to and during the kill. Entire pods can be beached at one time but this 'coordinated beaching' relies on the same social cohesion documented during the driving phase.

As the pod approaches the shore, intra-pod communication presumably becomes more difficult or breaks down altogether. Confusion within the pod will be increased by whales accidentally bumping into each other, and a decrease in water depth, affecting the sonar capabilities of the animals. This is shown by the change in diving patterns by the whales and the loss of social cohesion in the pod. It is unusual for the whole pod to be beached unless the beach is large or the pod small.

If the pre-beaching drive fails to strand the entire pod, those animals which have lost contact with the main pod continue to remain adjacent to the area. The animals exhibit behaviours such as spyhopping and tail-lobbing during this time. Both behaviours are known to indicate stress, and have only been recorded by the whales during this period of the hunt. After a certain amount of time, the animals re-group. Subsequent drives can then begin, when the behaviour patterns shown in the initial drive are repeated.

There are marked similarities in the behaviour of pilot whales during mass-strandings and in the pre-kill stages of the hunt. Pilot whales are one of the more commonly stranded cetacean species, and this is linked to their tight social cohesion (Martin, *et al.*, 1987). The final stage of the drive hunt in the Faroes also attempts to strand the whales. Evidence from strandings of pilot whales in New Zealand show that the animals will remain close to the area of a stranding and even re-beach themselves, drawn in by the vocalisations of the animals that remain beached.

In terms of percentage of animals that were beached and killed from the pod, the success of the drive hunt in the Faroe Islands is dependent on the pilot whales' social structure and behaviour. Similar behaviours have been documented in mass strandings.

REFERENCES

Amos, B., Barrett, J., and Dover, G.A. 1991. Breeding behaviour of pilot whales revealed by DNA fingerprinting. Heredity, 67 : 49-55.

Bloch, D. 1988. Driving of the pilot whale schools in the Faroe Islands (unpub.)

Bloch, D., Desportes, G., Hoydal, K., and Jean, P. 1990. Pilot whaling in the Faroe Islands July 1986-July 1988. North Atlantic Studies, 2 (1&2).

Evans, P.G.H. 1987. *Natural history of whales and dolphins.* Christopher Helm, London. 343 pp.

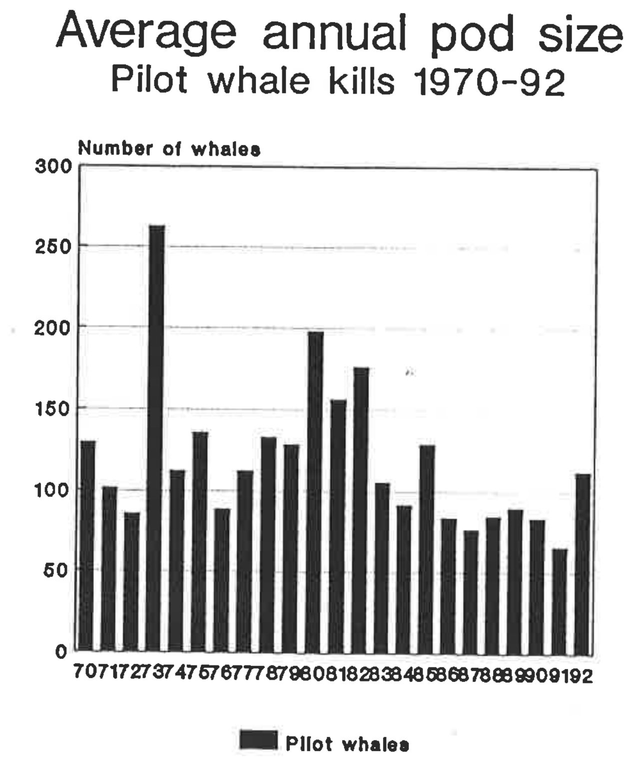
Faroese Museum of Natural History. 1986. Pilot whale statistics. unpub.

Faroese Museum of Natural History. 1987. Pilot whale statistics. unpub.

Heimlich-Boran, J. 1992. Short fins, long lives. BBC Wildlife, March 1992.

Martin, A.R., Reynolds, P., and Richardson, M.G. 1987. Aspects of the biology of pilot whales *(Globicephala melas)* in recent mass strandings on the British coast. J Zool. Lond., 211 11-23.

Taruski, A. 1979. The whistle repertoire of the North Atlantic pilot whale *(Globicephala melas)* and its relationship to behaviour and environment. pp345-368 in H.E.Winn and B.L.Olla (eds). *Behaviour of marine mammals, current perspectives in research.* vol 3. Cetaceans. Plenum Press, New York.



Source: official Faroese statistics

Fig. 1 Pod size of long-finned pilot whales killed in the Faroe Islands

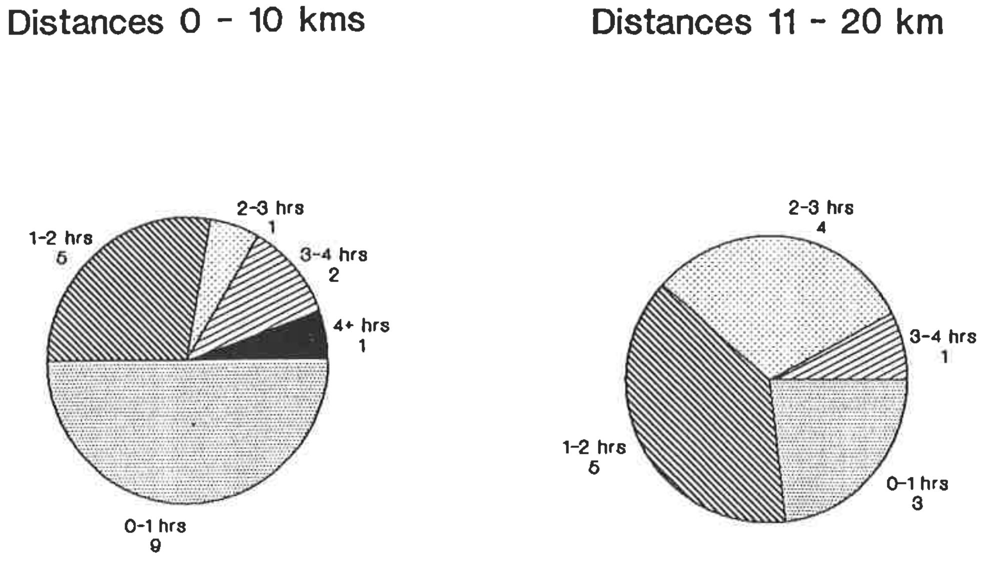


Fig. 2 Relationship between distance and time duration for 31 pilot whale drives in the Faroe Islands, 1986-88

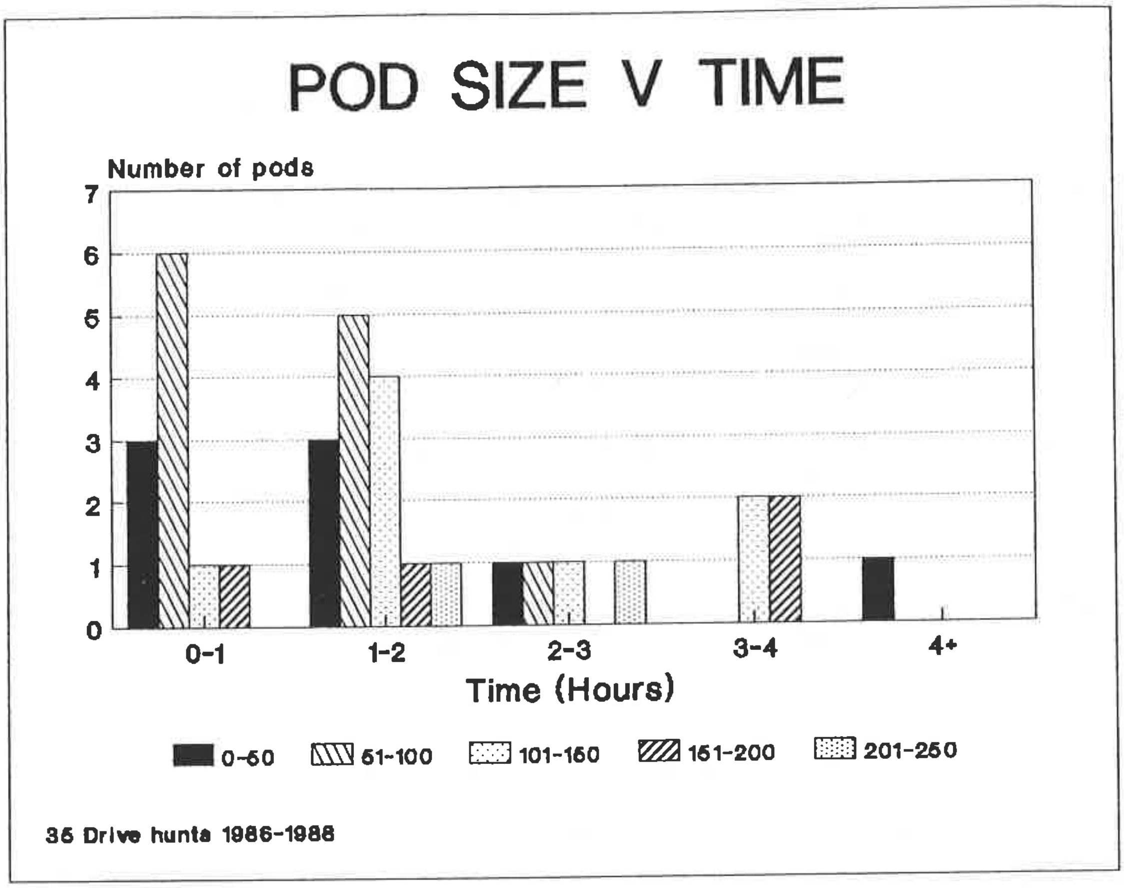


Fig. 3 Relationship between pod size and time duration for 35 pilot whale drives in the Faroe Islands, 1986-88

BEHAVIOUR OF LONG-FINNED PILOT WHALE *Globicephala melas* IN ALMERIA (S. SPAIN)

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In the week from 17 to 23 July, 1992 , we undertook an investigative cruise in the sailing boat "Toftevaag" (Alnitak Project). During the cruise we had the opportunity to see Common dolphins (*Delphinus delphis*), Striped dolphins (*Stenella coeruleoalba*), Risso's dolphins (*Grampus griseus*), and long-finned pilot whales (*Globicephala melas*).

On 23 July 1992, we observed a group of 40-60 long-finned pilot whales at 36° 42.6'N - 02° 03.2'W over a period of 117 minutes (see Fig. 1).

The group was made up of family subgroups that swam very near to the boat. We observed one jumping completely out of the water and it was interesting that another individual repeatedly opened its mouth directly at the boat. We also observed how another member showed its tail for some seconds, and then submerged.

There were two calves in two different subgroups. They swam near to their mothers, keeping their bodies further out of the water than the other individuals.

When we made a dive near one of the subgroups, they dived five metres underwater and made clicking noises at us; later, they whistled and withdrew by diving deeper; over the next twenty minutes, they remained some metres from us, looking inquisitively.

In the same month, there were six more observations in the same zone:

(1)-04/07/92	300-350 individuals
(2)-04/06/92	30- 35 individuals
(3)-16/07/92	40 individuals
(4)-17/07/92	200-300 individuals
(5)-27/07/92	80-100 individuals
(6)-29/07/92	50- 70 individuals

PROSPECTED AREA: ▨

Fig. 1 Location of long-finned pilot whale pod sighted off the Almeria coast, Southern Spain

PRESENCE OF "BABY-SITTING " MALES AMONG NORWEGIAN KILLER WHALES (*Orcinus orca*): ALLOPARENTING BEHAVIOUR AS AN INDICATOR OF SOCIAL COMPLEXITY

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INTRODUCTION Several species of social mammals have developed alloparenting systems where group members other than the genetic parents feed, protect, transport and play with the infants. This cooperative care of young has primarily been described for species organised into stable kin groups, and the alloparents are thought to benefit through inclusive fitness. Young female alloparents might also gain parental experience which prepares them for motherhood (Reidman, 1982).

The Norwegian killer whales are organised into groups of mixed ages and sexes, and since one objective for the on-going research on these whales is to reveal their social system, we considered a behavioural study on the alloparenting theme to complement the photographic and acoustic work. During the latest field season, we quantified associations between adult males and small calves and tried to evaluate if it was a rare phenomenon or not. Male-calf associations have two implications: Care-related behaviour above the level of mother-offspring may be obligatory for all mammals, and "baby-sitting" may occur as part of a reproductive strategy since the males of interest for the study were all sexually mature.

METHODS The fieldwork was conducted during late autumn 1992 in a small fjord area in northern Norway where several hundreds of killer whales reside due to the occurrence of wintering herring. The study takes advantage of two morphological characteristics of killer whales. The sexual dimorphism, which also separates immature and mature males, and the yellowish coloration of unweaned calves.

For a male-calf association to be valid, we required two criteria of distance and duration to be fulfilled: the calf had to be in echelon position with the male, slightly behind but in close proximity, thereby receiving a hydrodynamic "lift" during transport. The association had to last at least five minutes, which is the duration found for a corresponding study on Canadian killer whales. The pair also had to form a discrete unit with no other whale immediately nearby. Categorised behaviour and size/coloration of the calf were noted along with the associations. The observations were made rather opportunistically, and male-calf pairs were photographically identified whenever possible.

RESULTS AND DISCUSSION There was a total of 24 male-calf associations that lasted five minutes or more, providing a total observation time of 13 hrs 43 mins (range = 5 min to 5 hrs 43 min). The pairs occured when the whales were travelling, feeding or socialising and some of the calves were young enough to be regarded as unweaned. Two adult males (KA-1 and KA-2), known as a stable male pair since 1987, were observed to associate with one specific calf on four occasions during a time span of three weeks. These three whales took off on their "own expeditions" on two occasions, and spent several hours away from all the other whales in the area. The young whale, old enough to be weaned, seemed to prefer the company of one of the two males since he surfaced together with KA-1 for 92% of the time recorded on different occasions (n = 139).

It is hard to evaluate the function or even the significance of the observed male-calf associations. It is an interesting phenomenon, rare in the mammal world, but for the behaviour to be considered as "care" it should be measured in terms of increased survival of the calf. The practical difficulties in measuring calf survival are obvious, but the arguments for the calf receiving an energetic benefit while swimming in echelon position of a larger whale seems reasonable, so that"care" may at least be in the form of reduced cost of locomotion. Killer whales do not seem to spend energy in holding territories nor do they have to cope with predators, so the extra energy spent on carrying a calf may be a minor cost. Nevertheless, if one assumes that the presence of the calf affects the male, the obvious question is why would the male accept the role of "baby-sitter"?

One suggestion is that he has a genetic interest in the calf, and according to Hamilton's theory of kin-selection, the cost for the animal to act for the benefit of another is balanced by the degree of genetic relatedness between the two. There could also be social bonds rather than genetic ones which require a prolonged stability in group memberships. There are still a few data on the Norwegian killer whales to suggest either of these as possible explainations. For the Canadian killer whales the situation is different. Data on both genealogy and social organisation are available (Bigg *et al.*, 1990), and during a study of alloparental behaviour in this population, Waite (1988) demonstrated that adult males exclusively baby-sit their own siblings while young females would associate with any calf in the pod.

Since it is not possible to separate alloparental from parental care among the Norwegian killer whales, there is a risk of misusing the terminology for this particular behaviour. Animals that are fathering their own offspring are almost exclusively found within species having monogamous mating systems where paternity is certain (Clutton-Brock, 1991). Monogamy seems to be unlikely for killer whales forming multi-male/multi-female groups, so we have introduced the term "alloparenting" primarily to describe an individual that is not the mother of the calf. The two males that repeatedly associated with the same calf in an area with many calves available, indicate that there could be some sort of selection on male-calf formations. Since the associations occurred sufficiently frequently to appear as a behavioural characteristic of whales, any further studies on the subject might be based on theoretical predictions drawn from hypotheses on whether the males selectively baby-sit specific calves or not.

CONCLUSION Presence of "baby-sitting" by males among Norwegian killer whales indicates alternatives to uniparental care, where the female alone cares for the offspring, and to a traditional polygynous system where the only parental investment for an adult male is during copulation and nothing more, This might imply the presence of a relatively complex social system within killer whale populations.

ACKNOWLEDGEMENTS We thank Agnetha Säfsten for spending some time and energy in gathering "baby-sitting" observations, and the "Bella Crew" for their enthusiasm and open minds.

REFERENCES

Bigg, M.A., Ellis, G.M., Ford, J.K.B., and Balcomb, K.C. 1990. Social organisation and genealogy of resident killer whales *(Orcinus orca)* in the coastal waters off British Columbia and Washington State. Rep. Int. Whal. Commn. (Spec. Issue 12): 383-405.

Clutton-Brock, T.H. (ed.) 1991. *The Evolution of Parental Care.* Princeton University Press, New Jersey.

Reidman, M.L. 1982. The evolution of alloparental care and adoption in mammals and birds. Q. Rev. Biol., 57: 405-435.

Waite, J.M. 1988. Alloparental care in killer whales.*(Orcinus orca).* Masters Thesis. University of California, Santa Cruz.

UNDERWATER OBSERVATIONS OF COOPERATIVELY FEEDING KILLER WHALES (*Orcinus orca*) IN NORTHERN NORWAY

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INTRODUCTION Killer whales (*Orcinus orca*) in Norway feed on herring (*Clupea harengus*) using different techniques (Similä and Ugarte, unpubl. data). The aim of this study was to describe a method by which a group of killer whales feeds cooperatively on a school of herring very close to the surface. This method has been called carousel feeding, after Belkovich *et al.* (1991) who describe a similar method used by bottle-nosed dolphins (*Tursiops truncatus*) in the Black Sea.

MATERIALS AND METHODS During 1990-1992, killer whales were observed from a 10 m fishing boat in order to obtain identification photographs and behavioural observations. The fieldwork was carried out in northern Norway: around the islands of Vesterålen during summer and in Tysfjord and adjacent waters during October and November. Notes on behaviour and position were taken every ten minutes when whales were present and behaviour was recorded with a video-8 camera.

In 1990, we learned that a diver was not useful in making underwater observations of natural behaviour (the killer whales either went away or came to investigate the diver). In 1991 cooperation with the Australian Broadcasting Corporation provided us with a remote controlled underwater video camera manoeuvred from a zodiac. In 1992, we built a similar system with the addition of an almost silent electric engine that enabled us to steer the zodiac while making underwater video and sound recordings.

When analysing the capture of prey and the synchrony of movements from the underwater video, the whales were divided into two age/size categories: adult/sub-adult and juvenile/calf (whales less than 70% the size of an adult female).

RESULTS Carousel feeding has been observed only during autumn-winter. During October-November, 1990-92, killer whales were observed during 90 days (415 hours). Feeding whales were observed on 92 occasions (83 hours), of which 27 occasions (21 hours) were carousel feeding. Underwater observations of carousel feeding were made during 16 occasions, for a total of five hours.

A group of killer whales could be seen from the surface swimming actively round a school of herring, at times with fish jumping out of the water. Spyhopping was more frequent than during any other behaviour. The feeding session could last between ten minutes and three hours.

Underwater, killer whales were seen swimming under and around a school of herring, very close to the fish, frequently in groups of two or three (Fig. 1). Calves and juveniles were very active in these small groups. The whales often swam showing the white sides of their bodies towards the fish and sometimes emitted large bubbles close to the ball of herring. The whales stunned the fish by slapping with the flukes into the school. This tailslap produced a loud, banging sound. The whales ate only stunned fish (either stunned by them or by other whales). Juveniles could be seen doing tailslaps simultaneously with other juveniles or with an adult whale.

92 tailslaps were recorded close enough to the camera to estimate the size of the whale and the effect of the tailslap on the fish. The adult whales or sub-adult males were able to stun

one or more fish on 76.5% of their tailslaps, while juveniles or calves were efficient on only 36.6% of their attempts (Table 1).

During one of the complete underwater observations of carousel feeding, there was no background noise and it was possible to hear all the tailslaps. Figure 2 shows the amount of tailslaps in 15 sec. intervals. It took 3.5 minutes for the killer whales to drive the fish from 20-30m depth to the surface. The whales swam around the fish for almost 8 minutes before attempting to stun. Between 7.75 and 9.0 minutes there were three tailslaps. However, feeding did not start until after 10 minutes. There was a period of active feeding with a series of many slaps close to each other and gaps from 15 secs. to 1 min. during which whales were swimming around the fish and eating. The last tailslap came after 37.75 minutes.

Two different endings of carousel feeding were observed (Fig. 3): (1) The fish swam downwards and the whales left the area. Sometimes the whales started immediately to feed on a different school; (2) the whales left and the school of fish remained close to the surface for a period of time during which it might be overtaken by a different group of whales.

DISCUSSION The killer whales in northern Norway used a variety of methods to hunt herring. The method called carousel feeding is one of the few well documented examples of killer whales feeding cooperatively on fish. During this method, several whales herded a school of herring into a tight ball very close to the surface. The whales used the white undersides of their bodies and bubbles as visual stimuli to herd the fish. Juveniles were often swimming in a coordinated manner with adults or with other juveniles, and it is our impression that imitation could play an important role in learning the carousel feeding technique. The fact that juveniles were less efficient than adults at stunning fish and that they were often seen slapping simultaneously with other whales suggests that they were learning how to stun fish with a tailslap through imitation and practice.

The whales could spend up to ten minutes just swimming under and around the fish before they started eating. A similar situation has been observed when dusky dolphins *(Lagenorhynchus obscurus)* were feeding on anchovies in Patagonia (Würsig, 1991). It is possible that the whales were waiting for the herring to become lethargic due to overcrowding or stress.

Killer whales were seen only eating fish that had been stunned by a tailslap. This meant that the killer whales did not have to try to grab fast swimming fish with their teeth. If other odontocetes are also able to use their flukes as a weapon, they will not need to use loud vocalisations to stun prey, as suggested by Norris and Möhl (1983). However, it is not known if the tailslap stuns the fish due to physical contact, particle displacement or a sound wave.

Killer whales in Norway seem to live in stable groups (Similä & Christensen, 1992), probably family groups like killer whales around Vancouver Island (Bigg *et al.*, 1990), Patagonia (Hoelzel, 1991), or the Crozet Islands (Guinet, 1991). The whales in our study frequently ate fish stunned by another whale. Since all individuals in a group may be genetically related, the sharing of food observed during carousel feeding can be seen as an example of altruism with implications for kin selection.

The fact that the carousel feeding sometimes ended with the fish swimming downwards suggests that going deeper is an effective way for the fish to avoid predation. However, in some cases the fish remained close to the surface despite the risk of being overtaken by a group of killer whales.

One of the reasons why killer whales have adapted to very different environments could be that they are able to learn how to hunt different kinds of prey. They seem to live in stable family groups in which useful traditions like the use of a certain hunting technique could effectively be transferred from one generation to another.

AKNOWLEDGEMENTS This study has been funded by World Wide Fund for Nature, The Academy of Finland, Norwegian Council for Fisheries Research and the Whale Centre in Andenes. Inspiration and underwater video was provided in 1991 by David and Liz Parer and Peter Scoones. Various people have helped us in realising this study and we would like to thank especially Bertel Möhl, Rikke Hansen, Hanne Strager, Mads Christoffersen, Bo Johanneson, Mic Calvert, Anders Svensson, Åge and Helge Ingebrigsten, Björnar Engvik, Anna Bisther, Dag Vongraven, Svein Spjelkavik, Ann Åshild Hansen, and the Center for Studies of Whales and Dolphins.

REFERENCES

Belkovich, V.M., Ivanova, E., Yefremenkova, O., Kozarovitsky, L., and Kharitonov, S.B. 1991. Searching and hunting behaviour in the bottlenose dolphin (*Tursiops truncatus*) in the Black Sea. In *Dolphin Societies. Discoveries and Puzzles.* (Editors K.Pryor and K.Norris). University of California Press, Berkeley and Los Angeles. 390pp.

Bigg, M.A., Olesiuk, P., Ellis, G., Ford J.K.B., and Balcomb, K.C. 1990. Social organisation and genealogy of resident killer whales (*Orcinus orca*) in the coastal waters of British Colombia and Washington State. Rep. Int. Whal. Commn. (Spec. Issue 12): 383-405.

Guinet, C. 1991. Intentional stranding apprenticeship and social play in killer whales (*Orcinus orca*) Can. J. Zool., 69: 2712-2716.

Hoelzel, R. 1991. Killer whale predation on marine mammals at Punta Norte, Argentina; food sharing, provisioning and foraging strategy. Behav. Ecol. Sociobiol., 29: 197-204.

Norris, K. and B. Möhl. 983. Can Odontocetes debilitate prey with sound? Am. Nat., 122: 85-104.

Similä, T. and Christensen, I. 1992. Seasonal distribution and abundance of killer whales around Lofoten and Vesteralen islands, northern Norway. ICES. C.M. 1992/N:11

Würsig, B. 1991. Cooperative foraging strategies: an essay on dolphins and us. Whalewatcher, 1: 3-6.

Effect of tailslaps on the fish

WHALE SIZE	ONE OR MORE FISH STUNNED (%)	NO FISH STUNNED (%)	AMOUNT OF TAILSLAPS
ADULT/ SUB-ADULT	76.5	23.5	51
JUVENILE/ CALF	36.6	63.4	41

TAILSLAPS SEEN CLOSE:	92
TAILSLAPS SEEN:	231
TAILSLAPS HEARD:	525

Table 1. Effects of the tailslaps on the fish.

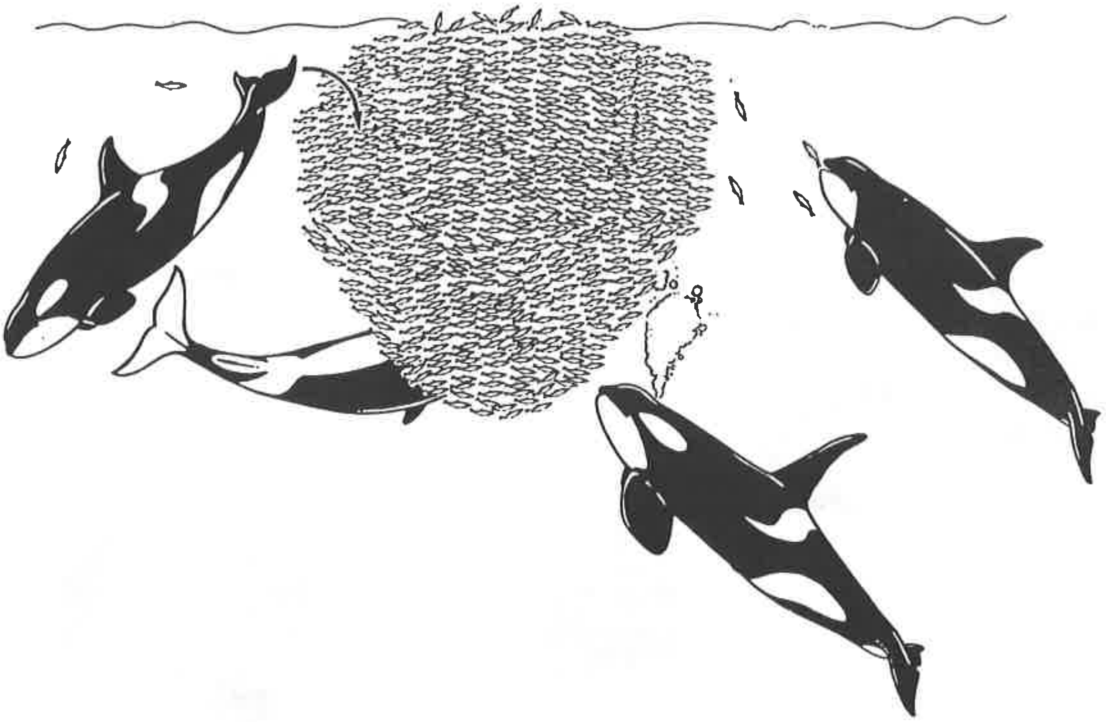

Fig 1. Carousel feeding: Whales stunning fish, showing white pigmentation, emiting bubbles and eating stunned fish.

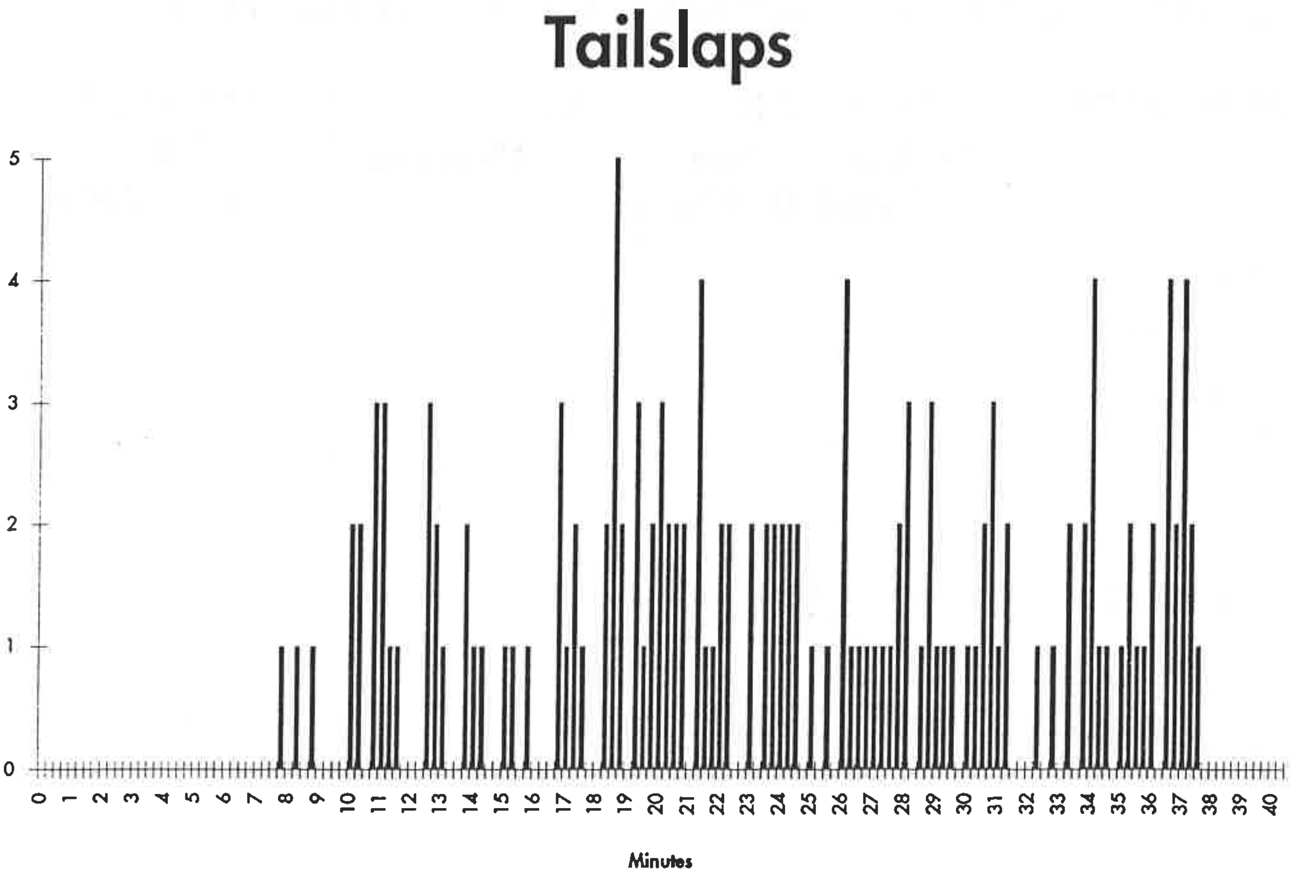

Fig 2. Amount of tailslaps used by the whales to stun fish in 15 sec. intervals during a complete feeding session.

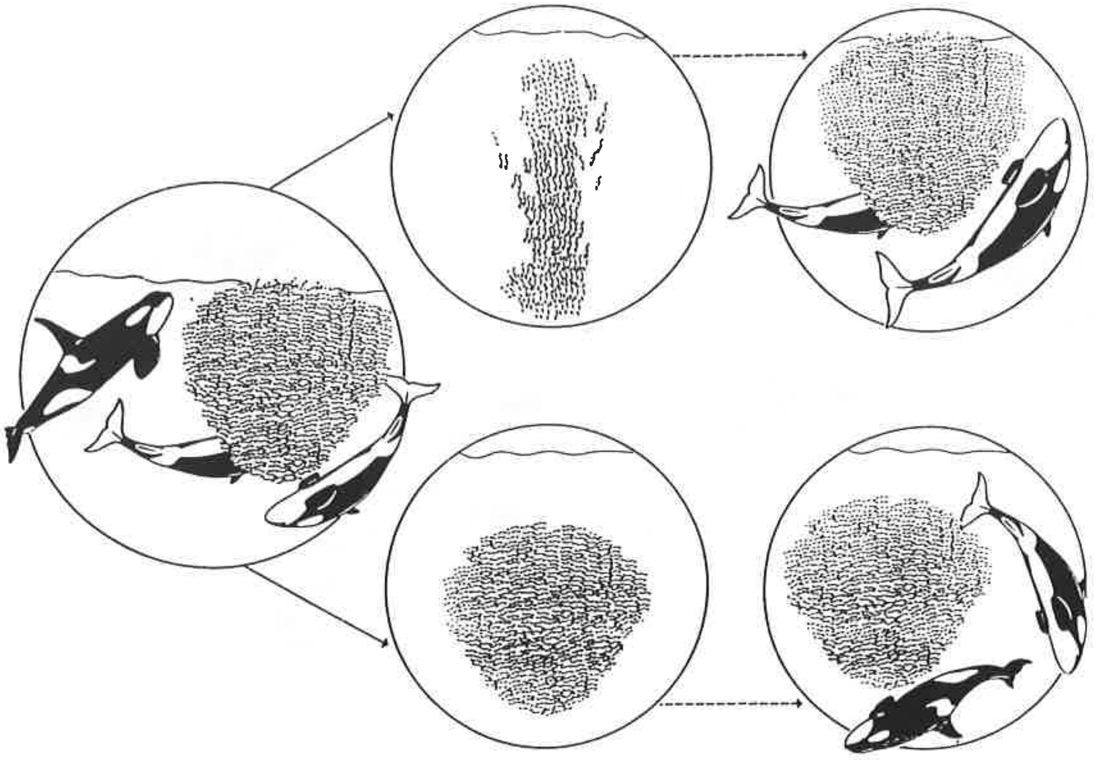

Fig 3. Different endings for the carousel feeding. In the first case the fish swim downwards and the whales leave the area. Some times the whales feed inmediately on a different school of herring. In the second case the whales leave the area and the ball of fish remains close to the surface. Sometimes the school of fish is overtaken by a different group of whales.

OBSERVATIONS OF THE UNDERWATER ACOUSTICS OF KILLER WHALES IN THE WATERS OF NORTHERN NORWAY

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Since 1983, a long term study on killer whale (*Orcinus orca*) population biology, social organisation and acoustic behaviour has been conducted in northern Norway. The study presented here was part of that project and contained an analysis of the vocalisations of nine photo-identified killer whale pods from the population in northern Norway.

The material was collected from 1986 to 1992 and contained about eleven hours of recording. Each of thenine killer whale pods had a unique repertoire of discrete calls but all pods also shared a smaller or greater portion of their repertoire with one or more of the other pods. These results generally confirmed the theory that dialects or vocal traditions are characteristic of killer whales.

Call complexes consisting of two or three different calls in different combinations was found in most recordings. The structure of these complexes appeared to be governed by syntactic rules. Complex call series have been reported previously from various species of birds and primates, but not from killer whales. The function of the call complexes is not understood but different hypotheses are discussed.

SOCIAL BEHAVIOUR OF HARBOUR PORPOISES: INSIGHTS FROM MORPHOLOGY

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Little is known about the social behaviour of harbour porpoises (*Phocoena phocoena*) because of the difficulties of studying these animals at sea. These are shy and elusive animals that possess few individually distinctive features, so standard observational techniques have afforded little insight into the behavour of this species.

It is possible, however, to make predictions about the social behaviour of harbour porpoises based on their morphology, which has been relatively well-studied. Such predictions allow us to formulate hypotheses that can be tested under field conditions. For example, male harbour porpoises possess relatively large testes and females are larger than males. These features are often associated with mating systems in which more than one male mates with each female in oestrus. Thus, it is likely that the social interactions of adult harbour porpoises are quite fluid during the mating system, unlike the more stable interactions that we see in single male mating systems (extreme polygny and monogamy).

The testes of male porpoises regress considerably in non-mating periods, however, and it is likely that this change in morphology is accompanied by behavioural modifications. We might predict, for instance, that male porpoises are less aggressive and more social in non-mating periods.

Finally, many females give birth to calves in successive years. Thus, the period of calf dependence is relatively short compared to other odontocetes, and calves must develop their behavioural and social skills at an early age. This attribute should make it possible to study interactions between calves and their mothers throughout the period of dependency and observe the dynamics of weaning and separation.

Although study of the social behaviour of this species will be challenging, we may gain considerable insight if we frame our hypotheses within existing theory and other aspects of the biology of this species.

FORAGING ECOLOGY OF HARBOUR PORPOISES IN SHETLAND

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INTRODUCTION The harbour porpoise *Phocoena phocoena* is Britain's commonest and most widely distributed cetacean (Evans, 1991). In recent years, the species has experienced widespread declines in Europe, becoming scarce or absent along the coasts of all countries bordering the southern North Sea. During the late 1970's and early 1980's, declines have also been recorded from a number of localities in northern Britain. The Shetland Islands in North Scotland have long been a stronghold of the species in Britain, but marked declines in porpoise numbers have been observed here during the 1980's (Evans, 1992). Whilst those declines have been taking place, there have also been major changes in local fisheries, particularly lesser sand-eels *Ammodytes marinus* but also other species (Kunzlik, 1989). The cause of those changes is still unclear. Although fishing pressure may have played a role, other factors may equally be involved, such as natural oceanographic changes and increased predation from fish species such as herring *Clupea harengus* as stocks recover (Bailey, 1991). Many seabirds (notably arctic terns *Sterna paradisaea* and kittiwakes *Rissa tridactyla*), known to be dependent upon sandeels, suffered massive breeding failure with chicks starving to death. The importance of sandeels in the diet of porpoises in the region is unknown although porpoises have been seen feeding upon them.

This project aimed to investigate more fully the possible relationship between observed porpoise declines and oceanographic changes, including changes in the stocks of various potential prey species. The main objective of the study was therefore to identify the major determinants of harbour porpoise distribution in the coastal waters of Shetland. Detailed aims included: (1) to determine distribution patterns of porpoises around Shetland, identify areas of concentration, and monitor status changes; (2) to relate spatial and temporal variation in the distribution of porpoises to the topography of the sea floor, tidal currents, and the distribution of major potential food fishes; and (3) to identify which fish species are most closely associated with feeding porpoises.

METHODS Fieldwork was divided between systematic land-based watches and regular dedicated cruises. The deeply indented coastline of Shetland strongly favoured the use of watches from strategic locations on land, since the greater viewing elevation provided a wider field of view and resulted in observations being less affected by variations in sea state conditions. Dedicated cruises were required for further examination of porpoise feeding ecology with colour echo-sounder surveys used to more precisely describe the undersea topography and to identify the presence of various fish species.

Regular systematic land-based watches for porpoises were carried out at Noss and Mousa Sounds in SE Shetland between May and October 1992. Watches totalled 205 hours at Noss Sound and 180 hours at Mousa Sound. These were supplemented by thirty boat transects (averaging 80 km per trip) in coastal waters between the islands of Noss and Mousa. During mid-August 1990, 1991 & 1992, systematic 100-minute watches were conducted at fifty locations around Shetland mainland and neighbouring Bressay, with additional boat surveys.

RESULTS

Population Surveys Porpoise numbers around Shetland (n = 50 sites) in August 1992 showed the first signs of a recovery from the declining numbers recorded in the previous decade(see Evans, 1992). The mean number per 100 mins. observation was 2.87 (SE 0.63) compared with a mean number per 100 mins. observation of 1.90 (SE 0.54) in August 1991.

During August, porpoises were widely distributed in Shetland but with regular concentrations on the east and south coasts of mainland Shetland. Areas with porpoise concentrations coincided with known sandeel fishing grounds, with two localities (Mousa Sound to Helliness, and south Noss Sound) being particularly important (Fig. 1).

Seasonal Variation in Porpoise Numbers Numbers of porpoises increased at both Mousa and Noss Sounds through the summer, lowest numbers occurring in June and highest numbers in August - September (Fig. 2a,b). On the other hand, the abundance of sandeels, gadoids (probably mainly saithe *Pollachius virens* and whiting *Merlangius merlangus*) and herring *Clupea harengus* in inshore waters, as revealed from echo-sounder surveys, all declined from July to October, particularly after August (Fig. 2c).

Although significant positive correlations between porpoise and gadoid abundance occurred in September ($r = 0.29$, $p < 0.05$) and October ($r = 0.50$, $p < 0.05$), there was either a negative correlation or no relationship for sandeels (data for herring were not used because of low sample sizes). When abundance indices of porpoises and prey were compared for Noss and Mousa Sounds only (where sample sizes of porpoises were highest), there were significant positive correlations between porpoise and both gadoid ($r = 0.74$, $p < 0.05$) and sandeel abundance ($r = 0.95$, $p < 0.01$), but only for Noss Sound in the month of September.

Diurnal Variation in Porpoise Numbers In Mousa Sound, porpoise numbers were highest during early morning (mainly from June to mid-August), and in the evening (mainly from mid-August to October). Most activity (93% of all observations) involved foraging or feeding. In the northern part of Noss Sound, porpoise numbers showed an evening peak, particularly associated with social activity, although generally during the day, the area was used mainly by transiting animals (61% of all observations). As at Mousa Sound, feeding occurred primarily in early morning, but also during evening hours.

Spatial & Temporal Relationships with Tide Porpoises foraged in Mousa Sound against the tidal flow, positioning themselves mainly at the northern end in mid-channel at the head of a basin into which currents bring potential prey. Feeding occurred at states approaching a turn of tide, i.e. 2-3 hours before and 3-5 hours after high water when current strength was at a maximum and beginning to decline again. This was particularly evident during spring tides. In Noss Sound, porpoise abundance increased with increasing current strength, with a peak in transiting animals occurring between two hours before high water and high water itself. Foraging (and social) activity peaked two hours after high water, again particularly during spring tides.

The mean number of porpoises present per ten-minute observation period was significantly greater during spring tides compared with neap tides ($t = 2.43$, $p < 0.05$). A comparison of two sample t-tests for diurnal and tidal data indicates that differences in porpoise abundance between spring and neap tides is more significant when organised by tidal state ($p = 0.002$) that diurnally ($p = 0.025$) (similar degrees of freedom), suggesting that tidal factors were more important than diurnal factors in determining suitable foraging conditions for porpoises in Mousa Sound. Most foraging porpoises were observed in water of depths varying between 20 and 30 metres.

DISCUSSION AND CONCLUSIONS A decline during the 1980's in numbers of porpoises in Shetland coastal waters in summer coincided with successive years of poor recruitment of young sand-eels into the adult population, and widespread breeding failure in a number of seabird species known to feed mainly upon sandeels. During summer 1992, sandeel stocks showed some recovery and seabirds had the first reasonably successful breeding season for seven years (Wright & Bailey, 1992). At the same time, porpoises showed the first sign of a recovery in numbers.

The two areas of south-east Shetland with highest porpoise abundance (Mousa and Noss Sounds) also supported high aggregations of sandeels and gadoids, whilst one of these (Mousa Sound) had by far the highest concentration of herring recorded. However, a detailed comparison of porpoise and prey distribution on a seasonal basis, showed little correlation. A number of possible explanations for this lack of correlation exist:

(1) Porpoises are feeding mainly upon other fish species not monitored by the echo-sounder surveys. These could include flatfish such as sole, dab and flounder which are all known to be taken by porpoises although thought to be present in insufficient numbers and of too low energy content to be favoured over those other species;

(2) Porpoises may be selecting a particular prey species, but this is obscured by the inability to distinguish, on the echo-traces, separate species within the family Gadidae. If spatial and temporal changes in abundance vary between gadoid species, these may give confounding results, which in turn could lead to a lack of association between predator and prey group.

(3) A superabundance of favoured prey, perhaps sandeels or one or more of the gadoid species, hmay have led to an absence of selection by porpoises for localised aggregations of fish of a particular species. Some support for this comes from the absence of significant correlations except during September when there was high porpoise abundance but low abundance of sandeels, herring and gadoids. Nevertheless this would not explain numbers of porpoises in the region continuing to increase during that month when those fish were showing marked declines in abundance.

(4) The geographical scale used to measure porpoise abundance does not match that of their potential prey and so might confound associations between the two. A patch scale analysis (see Schneider & Piatt, 1986 for details of methodology) that we have carried out has indeed highlighted the more random pattern of dispersion by porpoises compared with fish species which showed strongly clumped distributions. Future comparisons between porpoise and prey distributions might be best made at a finer scale.

(5) Boat transects are unable to clearly differentiate the various activities of porpoises, so that transiting animals or those engaged in social behaviour will have been included in association analyses of distribution patterns of porpoises versus prey species.

(6) Porpoises may move into inshore waters of Shetland for reasons other than high prey abundance. Numbers increase markedly during August at the end of the breeding season, alongside an increase in the percentage of calves present and an increase in time spent engaged in social activities. It may be necessary for adults to bring their calves into shallow waters so that they can start to feed independently of their parents and not have to dive too deep to capture food, particularly if it is demersal. The presence of energy rich fish (such as herring, mackerel and sandeel) could mean that total abundance need not be so very high, whilst also providing useful free time for social activities.

We have still some way to go before we can adequately test these different possible explanations, but attempts will be made to address them during subsequent field seasons.

ACKNOWLEDGEMENTS

Grants in support of this project were kindly provided by the World Wide Fund for Nature UK (through funds donated by Bulgari Ltd), the Shetland Amenity Trust, and Scottish Natural Heritage. Our grateful thanks go to all of these for making the project possible. We would also like to give warm thanks to Robbie Leask and Jimmie Birnie for skippering the

"Queen of Hearts" during boat surveys, and to Martin Heubeck, the staff of the SNH office in Lerwick, Ronnie Gallagher (Sullom Voe terminal), Terry Gorman, Jackie Henderson, John Scott, Chris and Anne (Wardens of Noss) and , Peter Wright and Martin Bailey of SOAFD (Aberdeen) for help at various stages of the project.

REFERENCES

Bailey, R.S. (1991) The interaction between seabirds and sandeels - a case history at Shetland. ICES CM 1991/L:41.

Evans, P.G.H. (1991) Whales, Dolphins and Porpoises: Order Cetacea. Pp. 299-350. In Corbet, G.B. and Harris, S. (ed). *The Handbook of British Mammals.* Blackwell, Oxford. 588pp.

Evans, P.G.H. (1992) Whales and Dolphins in Shetland Waters. *Shetland Bird Club Report, 1991*: 80-85.

Kunzlik, P. (1989) Small Fish around Shetland. Pp. 38-47. In Heubeck, M. (ed.) *Seabirds and sandeels*: Proceedings of a seminar held in Lerwick, Shetland, 15-16 October 1989. Shetland Bird Club, Lerwick. 81 pp.

Schneider, D.C. and Piatt, J.F. (1986) Scale dependent correlation of seabirds with schooling fish in a coastal ecosystem. *Mar. Progr. Ser.*, **32**: 137-246.

Wright, P.J. and Bailey, M.C. (1992) Biology of sandeels inthe vicinity of seabird colonies in Shetland. Second Annual Report. The Scottish Office Agriculture and Fisheries Department. *SOAFD Fisheries Services Report No.* 19/92, 26pp.

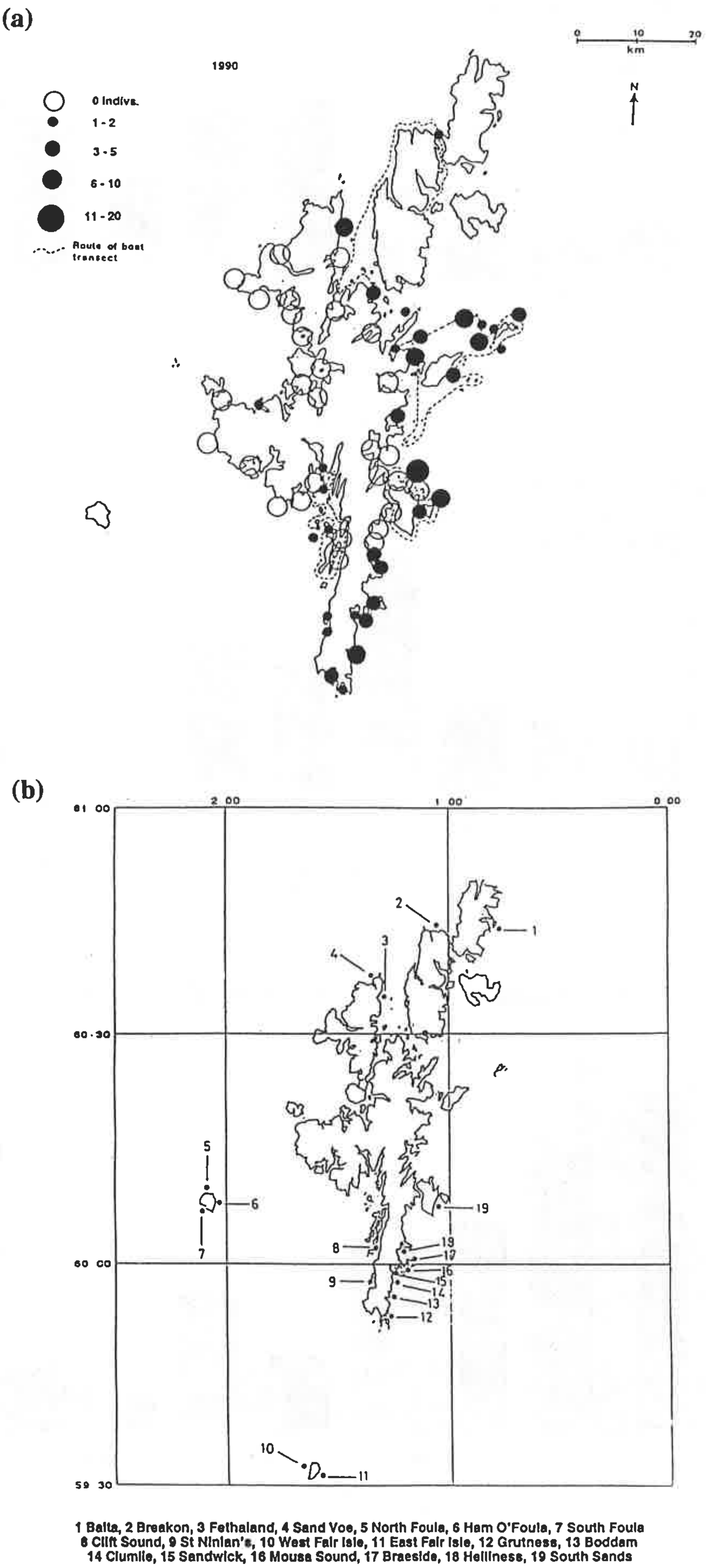
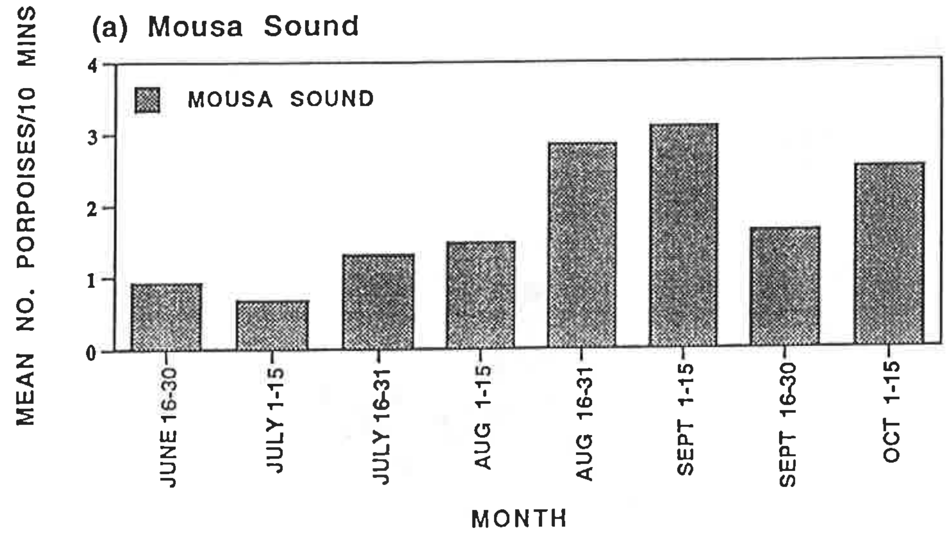
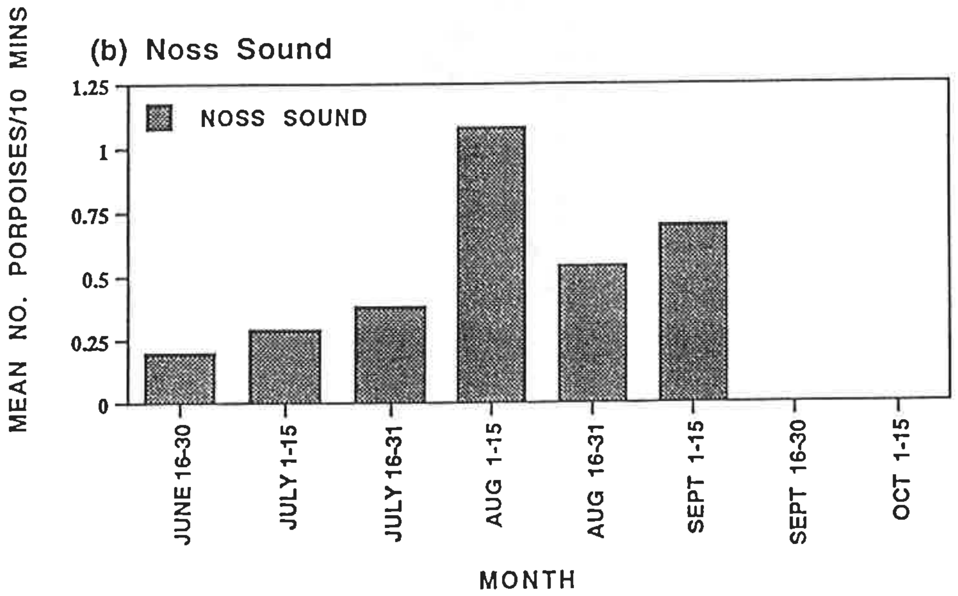


Fig. 1 **(a)** Distribution of harbour porpoises in Shetland from land-based watches and boat transects; and **(b)** Distribution of sand-eel fishing grounds in Shetland (from Kunzlik, 1989)





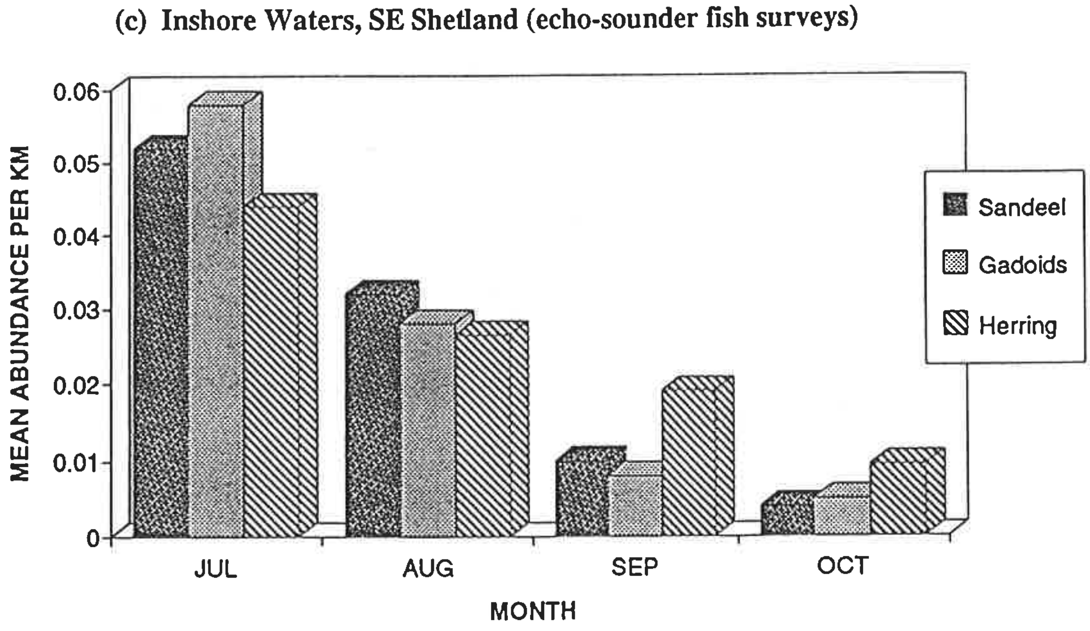


Fig. 2 Seasonal changes in Shetland waters in the abundance of (a) harbour porpoises, June - October 1992; and (b) sand-eels, gadoids and herring

OBSERVATIONS OF HARBOUR PORPOISE IN RAMSEY SOUND, DYFED

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INTRODUCTION The aim of this project was to investigate the relationship between harbour porpoise (*Phocoena phocoena*) activity and the tidal cycle. Objectives were to carry out observations from land collecting data concerning porpoise behaviour and associations, and to express this in relation to the time of the following high water.

Ramsey Sound separates Ramsey Island (51°51.5'N, 05°21.8'W) from the Welsh mainland west of St. David's, Dyfed (Fig. 1). The Sound is less than 1,000m wide at its narrowest point and tidal races form north of a reef of rocks, the Bitches, as the tide floods north, and in the south as the tide ebbs.

METHODS Fifty-three observation periods averaging 70 minutes each, were carried out from cliff-top on positions on the east coast of Ramsey Island on thirty dates between 7 September 1992 and 15 December 1992. Observations were carried out when conditions in Ramsey Sound were deemed such as to allow comparable detection rates between watches. During each watch the sea area was swept steadily back and forth in a systematic manner using 7x50 binoculars. At each sighting the following information was recorded: time, no. of individuals per group, direction of travel or orientation, estimated position, activity, presence and behaviour of nearby fauna, and additional notes on porpoise behaviour. Wind strength and direction, cloud cover and details of tidal flow were also recorded. Ramsey Sound was divided into three sections; total observer hours were not equally divided between the three (South Sound 38.45 hrs, Bitches 57.15 hrs, and North Sound 19.38 hrs). The number of sightings in each hourly period following high water (HW) has been divided by the total number of observer hours for each period to reduce variation due to differences in observer effort.

RESULTS

South Sound (257 sightings; 6.67 sightings.hr^{-1}) - porpoises were observed in this area between HW + 2.53 hrs and HW + 9.12 hrs (Fig. 3). 75% of sightings were of foraging behaviour in the ebb tidal race. 2.3% were travelling south, generally towards the beginning of this period; 8.9% were travelling north, generally towards the end of the period; 4.7% were milling; 8.9% were non-specific. When foraging, porpoises were observed for prolonged periods repeatedly surfacing with their heads oriented directly into the tidal stream. Groups of 1-8 were observed foraging but groups of more than three tended to be temporary associations which would disband after relatively short periods of intense, seemingly coordinated activity. Typical dive sequences when foraging were a series of short duration dives (4-7 secs) followed by a single longer dive (20-60.....180 secs). Northern gannets (*Sula bassana*) and greater black-backed gulls (*Larus marinus*) were frequently observed using porpoise as foraging cues.

Bitches (41 sightings; 0.72 sightings.hr^{-1}) - There were two distinct periods of activity in this area (Fig. 4). Between HW + 2.24 hrs and HW + 3.85 hrs, close to HW-slack, 66.7% of sightings were of porpoises travelling south. 12.5% were foraging; 4.7% were milling; 16.7% were non-specific; there were no sightings of porpoise travelling south.

Between HW + 8.58 hrs and HW + 9.68 hrs, close to LW-slack, 70.6% of sightings were porpoises travelling north. 11.8% were foraging, 17.6% were non-specific; during this period, there were no sightings of porpoises travelling south. Porpoises passing north through this area after having spent time foraging in the South Sound appeared almost to drift on the tide, surfacing at regular intervals, perhaps resting.

North Sound (30 sightings; 1.55 sightings.hr^{-1}) - Porpoises were seen in this area between 2.82 and 3.85 hrs after HW, and later in the tidal cycle, 8.28 to 11.05 hrs after HW (Fig. 5). During the first period 1 of 6 sightings were travelling south; 5 of 6 were non-specific. During the second period, 37.5% (9 of 24) were travelling north; 33.3% (n=8) were milling; 25% were non-specific. Little foraging was observed in the area (1 of 30 sightings).

DISCUSSION There was found to be little overlap between the times at which porpoise were sighted in the North and the South Sounds. The beginning and end of periods of activity in each area tended to coincide with the times at which the direction of flow of the tidal stream was reversed and overlap between sightings in different areas may be explained in part, by observed variation in the timing and duration of high and low water slacks at different stages of the spring-neap cycle.

As foraging behaviour was almost exclusively observed in the South Sound, and as the tide was ebbing, this suggests that porpoises were responding to an increased probability of finding food there at that time. Pelagic, shoaling species upon which harbour porpoises are reported to prey (Smith & Gaskin, 1974) may become concentrated below the tidal race either by the ebb flow itself and bottom topography (Fig. 1), or themselves having taken advantage of an increased prey density in the area. Porpoises would then benefit from a concentration of prey items which may otherwise have a more dispersed distribution. The sides of the deep water channel through which the tide flows may assist porpoises to herd and capture prey.

Porpoises in the Bay of Fundy are reported to spend up to 76% of their time foraging whilst following similar patterns of movement from day to day (Watson, 1976). Although it has not been established whether individual porpoise maintain a circa-tidal rhythm of activity in the area, the data show that there is clearly a strong tidal influence on the foraging behaviour and movements of harbour porpoise in Ramsey Sound.

REFERENCES

Smith, G.J.D. and Gaskin, D.E., 1974, The diet of harbour porpoise *(Phocoena phocoena)* in the coastal waters of eastern Canada, with special reference to the Bay of Fundy. Can.J.Zool., 52: 777-782.

Watson, A.P., 1976, *The diurnal behaviour of harbour porpoise* (*Phocoena phocoena* L.) *in the coastal waters of the Bay of Fundy.* MSc thesis, University of Guelph, Ontario.

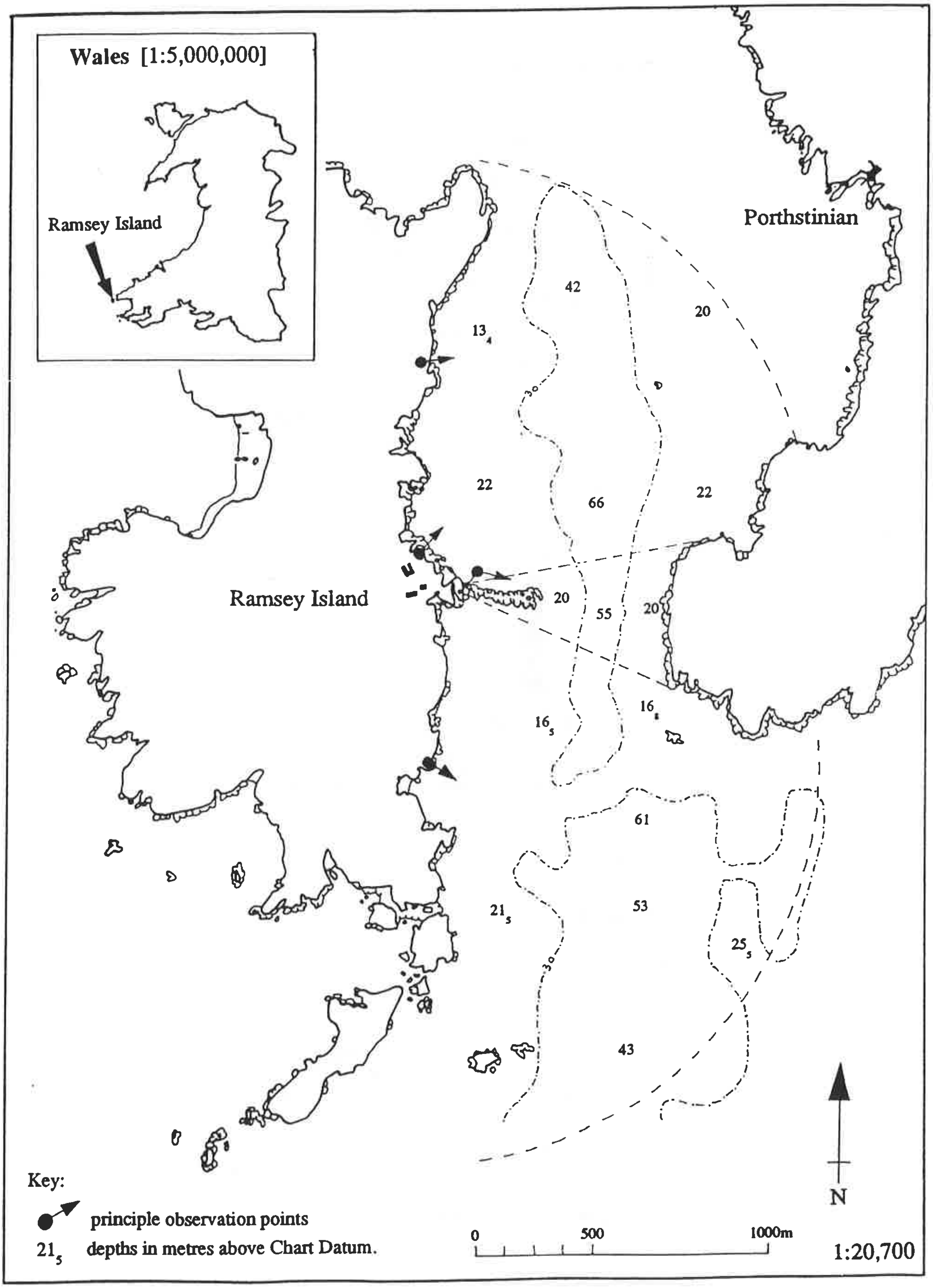

Fig. 1 Map of Ramsey Sound, Dyfed (after Admiralty 1983)

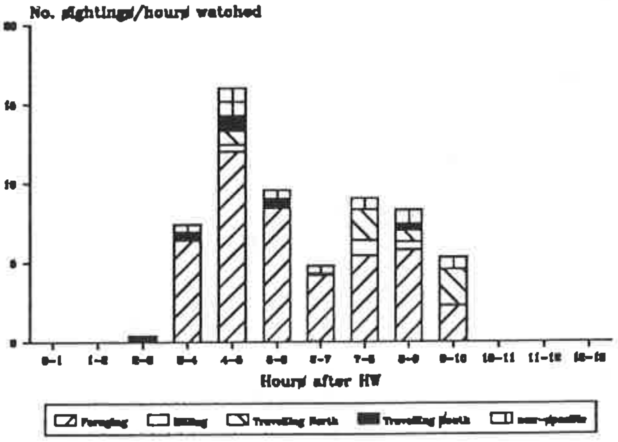

Fig. 2 Porpoise Activity in relation to Tidal State, South Sound

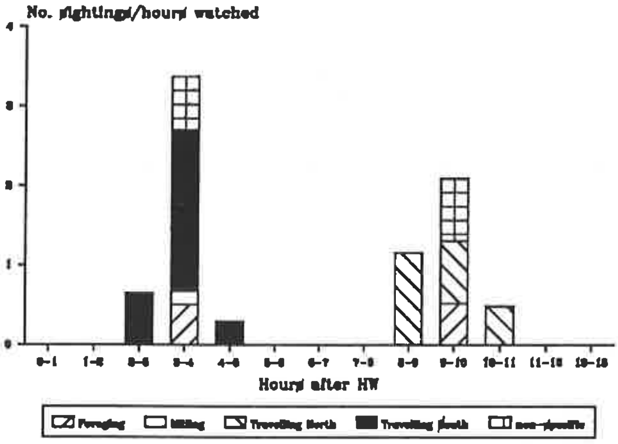

Fig. 3 Porpoise Activity in relation to Tidal State, Bitches

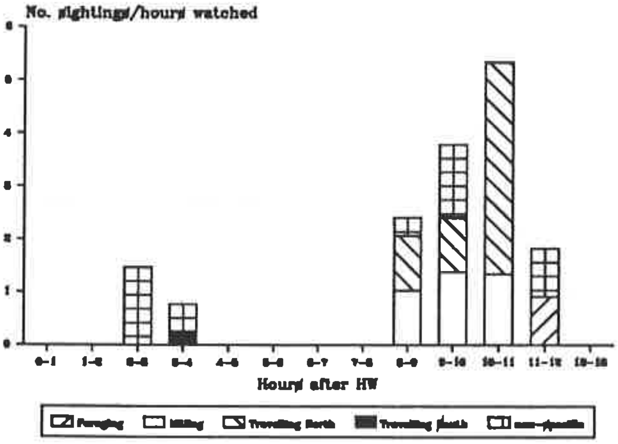

Fig. 4 Porpoise Activity in relation to Tidal State, North Sound

SOME ASPECTS OF SOCIAL BEHAVIOUR OF HARBOUR PORPOISES (*Phocoena phocoena*) WITH EXAMPLES OF THEIR INTERACTION WITH BIRDS, SEALS AND HUMANS, OBSERVED FROM THE BEACH OF SYLT, GERMANY

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For some years, we have been able to regularly observe harbour porpoises (*Phocoena phocoena*) near the beach of the Isle of Sylt. Some unusual behaviour and interactions could be observed frequently. Total number of observations observed between 1991 and February 1993 were 122, comprising 194 harbour porpoises (Fig. 1). Observation time ranged from several minutes to 3.5 hours.

1. SOCIAL BEHAVIOUR

There are special areas along the beach where harbour porpoises appear regularly. Sometimes, in the course of several days, animals would arrive at the same time of day and, regardless of the tides, at the same places near the beach. We often saw mother-calf groups or single animals. Occasionally, both categories of groupings appear together. Because of our regular observations and the experience we obtained in comparing the animals according to their size, we could say that, as a rule, the same animals appeared in the same area. There seem to be particular zones along the beach with lateral boundaries (beach and sandbanks) that some animals consider as their territory which, at least for some time they regularly visit. As individual identification of the animals was impossible under these circumstances, we cannot say definitely how long the same animals stayed in the same zone. A regular and daily observation is only possible when the sea is calm and the waves are not higher than one metre.

Quite often, two groups (mother-calf and single animal) meet. One of the animals sprays water with its fluke. This seems to be a defence reaction, since the groups separate following this action. In some cases, the mother-calf group definitely appeared to dominate since the medium-sized single animal departed. It may be that this was a smaller male or a young one from the previous year.

On one occasion we video-taped a situation where two harbour porpoises breached out of the water at the same time (1 Dec, 1990). This may have involved contact between the two sexes (C. Kinze, pers. comm.).

Only once did we observe a mother-calf group in the bay that was surrounded by sandbanks and the beach. The mother was hunting along the inner side of the farthest sandbank, whereas the calf resting, from time to time at the surface of the water, was swimming in the bay which had little current. This occurred in August, when the calf was still young and was probably being fed only with its mother's milk. The calm bay appeared to be a "safe" haven in which the calf could stay in a limited area and the mother could be at ease whilst hunting.

So far, no harbour porpoise with a very young calf has been recorded in the northern part of the island, in the so called Lister Tief where there are strong tidal currents up to 1.3 m per sec. and where ship traffic is frequent during daytime.

On the beach of the city Westerland, Isle of Sylt, some flat breakwaters go into the sea. When the tide is going out, they jut out. At low tide, the deepest spots in front of the head of the breakwaters are approximately 3.5m deep. Between the stones, we could discover the following animals by scuba diving: *Mytilus edulis, Littorina littorea, Crangon crangon,* *Pagurus bernhardus, Cancer pagurus, Liocarcinus holsatus, Carcinus maenas, Asterius rubens, Syngnathus acus, Gadus morhua,* juv., *Merlangius merlangius,* juv., *Hyperoplus lanceolatus, Ammodytes lancea, Pholis gunnellus, Zoarces viviparous, Pleuronectes platessa, Limanda limanda, Callionymua lyra,* and*Anguilla anguilla.*

It is only in the vicinity of these flat breakwaters that harbour porpoises can often be observed hunting. In October 1992, we repeatedly observed a mother-calf group. Parallel to the beach, the animals were swimming synchronously at high speed. Along the breakwater, they would dive for a long time, swimming slower underwater than before. In front of the head of the breakwater, they both came up to breathe. Then they continued diving along the other side of the breakwater back to the shore. The time they stayed underwater was comparatively long for the short distance they had to swim. After that, both animals speeded up and swam parallel with the beach to the next breakwater. As before, they slowly dived around it, before accelerating in order to get to the next breakwater. It appeared as if the calf was receiving a "school lesson" on animals as prey and how to find them.

In December 1992, we repeatedly observed a (the same?) mother-calf group that was swimming synchronously near the shore and was hunting. Suddenly, one animal swam out to open sea where it could sometimes be seen at a distance of about 1km from the beach, still hunting. It stayed there for up to one hour. The second harbour porpoise stayed in a smaller area of about 100m width near the shore until the other came back. After that, both swam parallel to the shore until again they separated and hunted in different areas, one near the shore, the other farther off. Possibly when the calf hunts alone, its parent does not wish to disturb it by being present.

The behaviour described above, illustrates how a harbour porpoise mother associates with its calf at different stages. A very young calf may be left in an area with little current whilst the mother fishes nearby. Later on, the young travels with the adult to the fishing ground and it is taught where to find specific prey. From a certain phase of development and during weaning, the young harbour porpoise has to attempt to catch prey and learn to hunt on its own.

Harbour porpoises may be seen sleeping just below the water surface particularly after strong westerly winds and high waves followed by a calm sea, mostly with wind from the east. After the mother and calf had been sleeping, they would dive synchronously in the same direction but then come up independently to rest on the surface of the water. Seemingly they described a circle underwater when sleeping. By so doing, they avoid drifting far from each other.

INTERACTIONS BETWEEN HARBOUR PORPOISES (*Phocoena phocoena*) AND OTHER ANIMALS

Birds We often observed eiders *(Somateria mollisima)* flee, panic-stricken, when a harbour porpoise appeared. On the other hand, eiders kept on swimming calmly near harbour porpoises and even dived for food. After many observations, we noticed at least one harbour seal *(Phoca vitulina)* would hunt and even eat these ducks. As a result, whenever they saw a dark back, the birds fled to the shore, even if it was a human being. Seemingly, they calmed down when they saw a triangular dorsal fin.

Whenever we see groups of ducks in particular areas on the water, we watch those spots carefully, particularly if the birds suddenly start flying. This alerts us in some cases to where to watch harbour porpoises. Gull species (*Larus argentatus, Larus ridibundus, Larus canus*), however, do not react at all to harbour porpoises. Twice we saw a harbour porpoise appear directly under a herring gull. The bird slipped off its back, kept its own balance using its wings, and went on swimming calmly. The other herring gulls that were nearby did not react. Harbour porpoises can be seen "sleeping" between herring gulls and eiders near the flat breakwaters. Indeed, it is quite difficult to distinguish harbour porpoises between the birds.

Seals Harbour seals (*Phoca vitulina*), grey seals (*Halichoerus grypus*), and harbour porpoises can often be observed hunting in the same areas. Especially when there are swarming fish like mackerel (*Scomber scombrus*), both seals and harbour porpoises hunt side by side in narrow areas. Sometimes they appear in the same zones of the beach where there are flatfish (*Pleuronectes platessa, Limanda limanda*). But here they hunt separately. In most cases the harbour porpoises arrive first. Sometimes the seals follow the harbour porpoises at a distance of about 200m.

Harbour porpoises appear not to be afraid of grey seals. At the end of July, a harbour porpoise mother was observed swimming with her newborn calf very close by a female grey seal. The calf must have been very young, because it stuck its head completely out of the water when breathing. The harbour porpoises did not change their direction and came up to breathe at a distance of about 20m both in front and behind the grey seal.

Human beings Since harbour porpoises (and seals) regularly hunt in the same areas near the beach, they can be taken as indicators of good fishing areas. This information is actually incorporated into the angler instruction program on Sylt. We found on several occasions that some minutes after foraging harbour porpoises (or seals) have left the area, flatfish bite well again.

However, harbour porpoises are also threatened by anglers. On 14 September 1991 at the first ECS workshop on cetacean pathology in Leiden, Netherlands, a fish hook with special bait-system for big game-fishing was found in a dead porpoise. Cause of death was a rupture of the stomach (John Baker, University of Liverpool, pers. comm.). Porpoises, dolphins and seals are also endangered by fishing of mackerel using a mackerel-feather-system (4 to 6 hooks), pilker with triple-hook and ground-fishing from a boat or from the shore. At Sylt, harbour porpoises approach small fishing boats. Some anglers in fact lure the harbour porpoises just for fun by hitting the water with their flat hands.

Since harbour porpoises often come close to the beach of Sylt, sometimes as near as 10m from the beach, the fishing of ground-fishes is also a danger for them. The fishing-line can be thrown out very far, even up to 80m. They may get caught in the fishing-lines or be harmed by fishhooks. If a flatfish that has swallowed the bait is itself eaten by a harbour porpoise, the porpoise will also swallow the fish hook. It also may be that a small flatfish notices the coming porpoise. The fish tries to escape and to hide itself in the sand, but it is hanging on a hook and line. The harbour porpoise notices the pulling fish and takes it as an easy prey. On one occasion we observed a harbour porpoise that swam over a fishing-line quickly stop and come back. We are convinced that the porpoise was interested in the fishing gear under the water, perhaps in a fish close to the worm on the hooks. After some time it continued on its former course.

Harbour porpoises usually avoid crossing crab cutters and pleasure steamers. These ships travel slowly and on a steady course. This makes them predictable for the animals, which do not panic but swim back to the place they had been after the ship has passed.

Jet-skis, jet-bikes and speed-boats (with water-ski or para-sailing) are faster (up to 65km/h), louder and often change their direction. This makes them unpredictable for harbour porpoises. These sports are practised mainly during the summer, when porpoises (and harbour seals) are born. When these sporting boats were on the water, we could not observe any harbour porpoises at the same time in those areas in which they normally occur.

Surfers repeatedly told us that harbour porpoises surfaced directly next to them, at a distance of about 2-4m when they had been wave-riding. Some surfers were frightened because of the triangular dorsal fin, and fell off the board. Harbour porpoises frequently approach swimmers who get frightened because they think of sharks when they see the triangular dorsal fin. For this reason some swimmers have been afraid of swimming back from a sandbank to the beach while two porpoises have been fishing in that area. Repeatedly, swimmers-even biologists!-would panic when they saw large animals with a triangular dorsal fin swimming towards them and diving in their direction only some metres in front of them.

The first author himself has been swimming with harbour porpoises. One day a group of harbour porpoises swam in a semi-circle around him and then followed their former direction. On a second occasion, a group of six harbour porpoises (four adults, two juveniles) surrounded the swimmer and approached up to 5 or 7 m away. On another occasion, they would have been 2 m behind the first author, but he did not notice them. Unfortunately, visibility underwater is poor. Up to now, it has not been possible to film or take still pictures of porpoises underwater.

REFERENCES

Benke, H., Kremer, H., and Pfander, A. 1991. Incidental catches of harbour porpoise (*Phocoena phocoena* L. 1758) in the coastal waters of Angeln and Schwansen (Schleswig-Holstein, FRG) from 1987 to 1990. *European Research on Cetaceans - 5*. Proc. 5th Ann. Conf ECS (Editor P.G.H.Evans). European Cetacean Society, Cambridge, England. 254 pp.

Evans, P.G.H. and Gilbert, L. 1991. Distributional ecology of harbour porpoise in the Shetland Islands, North Scotland. *European Research on Cetaceans.- 5*. Proc. 5th Ann. ECS Conf., Eds. P.G.H.Evans). European Cetacean Society, Cambridge, England.

Kinze, C.C. 1988. Studies on behaviour and ecology of the harbour porpoise (*Phocoena phocoena*) Preliminary results from a series of sighting cruises in Danish waters, April - August 1987. *European Research on Cetaceans - 2*. Proc. 2nd Ann. Conf. ECS (Editor. P.G.H. Evans). European Cetacean Society, Lisboa, Portugal.

Schulze, G. 1987. *Die Schweinswale*. A. Ziemsen Verlag, Wittenberg Letherstadt.

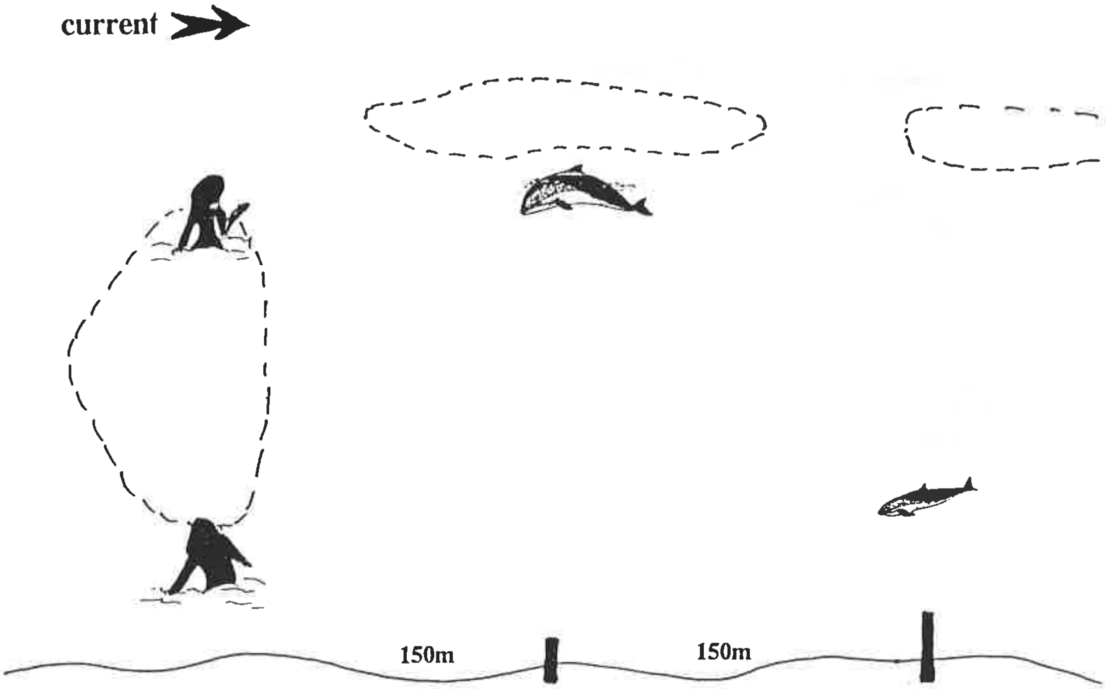

Fig. 1 The current was only outside this bay bordered by the sandbanks. The harbour porpoise calf swam around alone and sometimes was sleeping on the surface, whereas the mother was fishing in front of the sandbank.

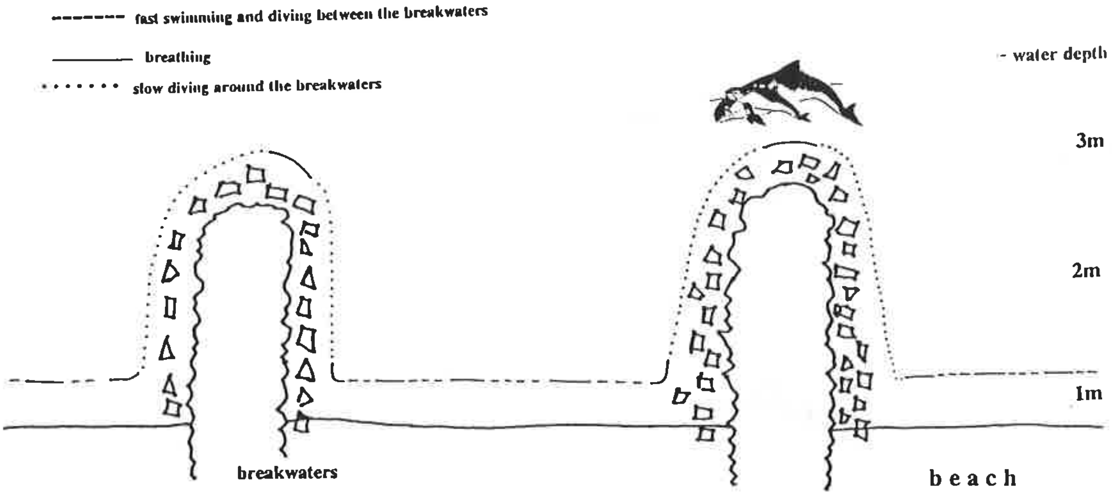

Fig. 2 The flat breakwaters on Westerland beach, regularly feeding area of harbour porpoises. Between 2 breakwaters mother and calf traveling in high speed, but in low speed diving around them. It seemed as if the young animal got a "school-lesson" in animals as prey and how to find them.

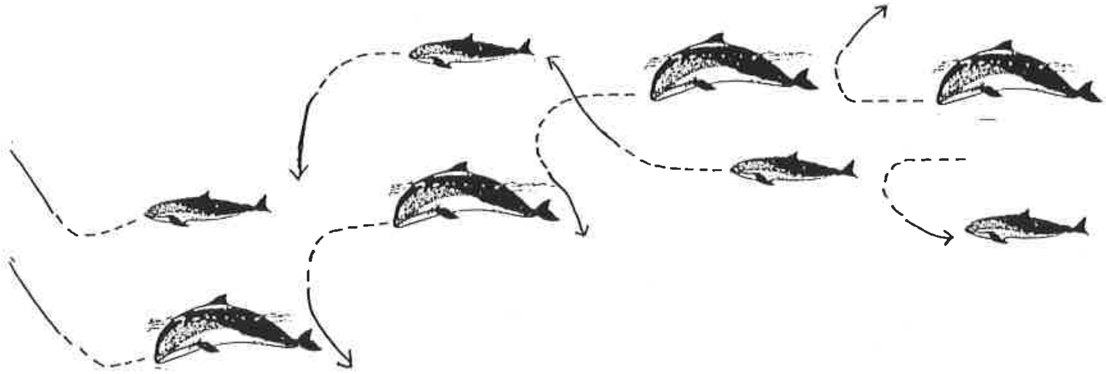

Fig. 3 "Sleeping-pattern" from mother and calf: when starting the underwater sleeping the animals seem to "lay" themselves on their right or left side. So they make a semicircle and stay close to another. Between surface sleeping and new underwater sleeping they breath 3 to 5 times.

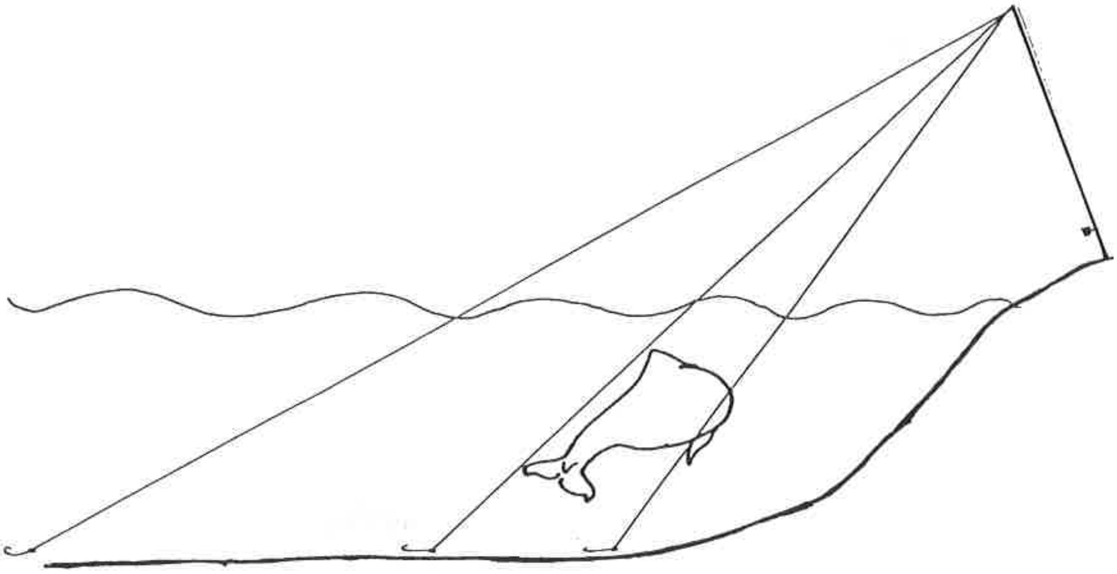

Fig. 4 Harbour porpoises regularly are fishing very close to the beach, anglers also do. Best sport-fishing is where harbour porpoises and seals are fishing, for example near breakwaters or in deeper coastal parts near the beach. Fishing-lines are dangerous for sea-mammals, especially when taking the line with the body it is possible the animal hurts itself with the hooks at the end of the line.

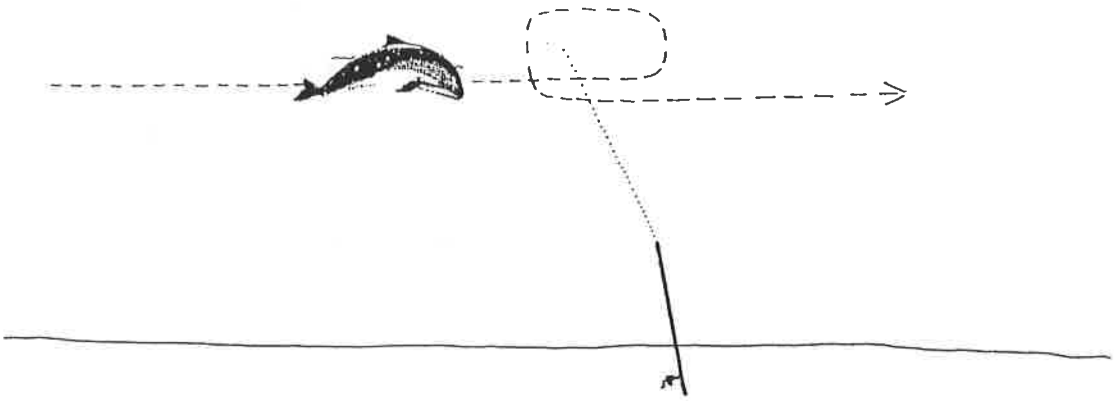

Fig. 5 A traveling harbour porpoise swam over a fishing-line, turned at once. I am sure the porpoise was interested in the fishing-equipment under the water, maybe in a fish nearby the worm on the hooks. After some time it swam on in its old direction.

INVESTIGATIONS OF HARBOUR PORPOISE VOCALISATIONS

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INTRODUCTION Although the harbour porpoise is the commonest inshore odontocete in European waters, its acoustic behaviour, especially in the wild, has been surprisingly little studied. Most recent investigations have found that porpoises only produce clicks within which sound energy is concentrated in two widely separated frequency bands: a high frequency band at around 130 kHz and a much less intense low frequency band at around 2KHz (Dubrovskii *et al.*, 1971, Møhl and Andersen 1973, Kamminga and Wiersma 1981, Hatakeyama and Soeda, 1990; Amundin, 1991a). Amundin (1991b) described patterns of click trains from captive harbour porpoises with repetition rates as high as 1200 clicks.sec^{-1}. Some patterns seemed to be correlated with certain behaviours and it was suggested that others could function as signature calls.

In this study we were interested in characterising the vocalisations heard from free-ranging porpoises in the field.

METHODS Harbour porpoise vocal behaviour was studied through the summer of 1992 from the International Fund for Animal Welfare's research vessel "Song of the Whale". The two main study areas were Loch Alsh on the west coast of Scotland and the Moray Firth on Scotland's east coast.

Recordings were made using a broad-band (20-200 kHz) hydrophone system and a Racal Store 141 tape recorder running at 30 or 60 ips. A customised harbour porpoise detector, utilising an envelope tracing principle, was designed and built. This made the ultrasonic vocalisations of harbour porpoises detectable within the human auditory range. In the presence of harbour porpoises continuous recordings were made in stereo onto digital audio tape using a Sony TCD10 Pro tape recorder. The output from the detector was recorded on one channel, and the other channel recorded output from a 200 Hz to 20 kHz hydrophone system. Such extended recordings were used to investigate patterns of click production and monitor for the low frequency component of porpoise clicks.

For analysis, 141 recordings were typically played back at 1/16th speed and sampled at 40 kHz with a Cambridge Electronic Design (CED) 1401 digitiser. CED "Mass Ram" and "Waterfall" software were used to depict waveforms and spectra of clicks and to measure click rates.

RESULTS AND DISCUSSION Only click vocalisations were recorded from harbour porpoises.

Click characteristics A typical click consisted of a short pulse of sound (mean duration 0.19 msec) with a narrow band of frequency emphasis (mean peak frequency 127.8 kHz) (for example Figs 1 and 2). None of the low frequency pulses reported by previous workers were detected. This could be due to the reported lower intensity of this component of the animal's vocalisations.

Clicks within sequences showed consistent waveforms and frequency emphasis. However, there was some variation (between 120 and 140 kHz) in the peak frequency of the clicks analysed (Fig. 3). Pulses which were part of "buzz" vocalisations had lower emphasised frequencies (median 122.0 kHz) than clicks which were part of "slow clicking" vocalisations (median 130 kHz) (Mann-Witney 'U' test p = <0.01).

There are some indications that emphasised frequencies may vary between individuals and locations, and that two individuals vocalising at the same time may use different frequencies. However, further research is required to confirm this.

Patterns of click production Clicks were typically made as part of short fast "buzz" vocalisations or during "slow clicking" vocalisations. "Buzzes" were only recorded when porpoises were very close to the hydrophones. They may represent a more intense form of echolocation than "slow clicking".

The mean duration of a "buzz" was 0.53 sec. Click repetition rates during a "buzz" typically started at a lower rate (mean 333.86 clicks sec^{-1}), increased to a higher sustained rate (mean 436 click sec^{-1}) and fell to a mean rate of 366 sec^{-1}, by the end (Fig. 4). Rates of clicking during "slow clicking" vocalisations ranged from 1.1 to 75 clicks sec^{-1} with a mean of 15.40 clicks sec^{-1} (Fig. 5).

ACKNOWLEDGEMENTS This work was funded by the International Fund for Animal Welfare with the help of a grant from the European Commission through the Eurogroup for Animal Welfare. Fieldwork in the Moray Firth was conducted in collaboration with the Lighthouse Field Station of the University of Aberdeen.

The Racal 141 tape recorder was donated by Racal and the high frequency hydrophone by Marconi Underwater Systems to Dr Peter Evans and loaned to this project by him.

REFERENCES

Amundin, M. 1991a. Helium effects on the click frequency spectrum of the Harbour porpoise. *Phocoena phocoena.* Pp. 63-74. In *Sound Production on Odontocetes, with emphasis on the harbour porpoise, Phocoena phocoena.*

Amundin, M. 1991b. Click repetition rate patterns in communicative sounds from the Harbour porpoise, *Phocoena phocoena.* Pp. 91-111 In *Sound Production on Odontocetes, with emphasis on the harbour porpoise, Phocoena phocoena.*

Dubrovskii, N.A., Krasnov, P.S., and Titov, A.A 1971. On the emission of echolocation signals by the Azov harbour porpoise. Sov. Phys. Acoust., 16: 444-7.

Hatakeyama, Y and Soeda, H. 1990. Studies on echolocation of porpoises taken in Salmon gillnet fisheries. In: *Sensory abilities of Cetacea.* (editors J. Thomas and R. Kastelein) Plenum, New York.

Kamminga, C. and Wiersma, H. 1981. Investigations on Cetacean sonar II: Acoustical similarities and differences in Odontocete sonar signals. Aquat. Mammals, 8: 41-62.

Møhl, B. and Andersen, S.H. 1973. Echolocation: High frequency component in the click of the harbour porpoise (*Phocoena phocoena* L.). J. Acoust. Soc. Am., 54: 1368-72.

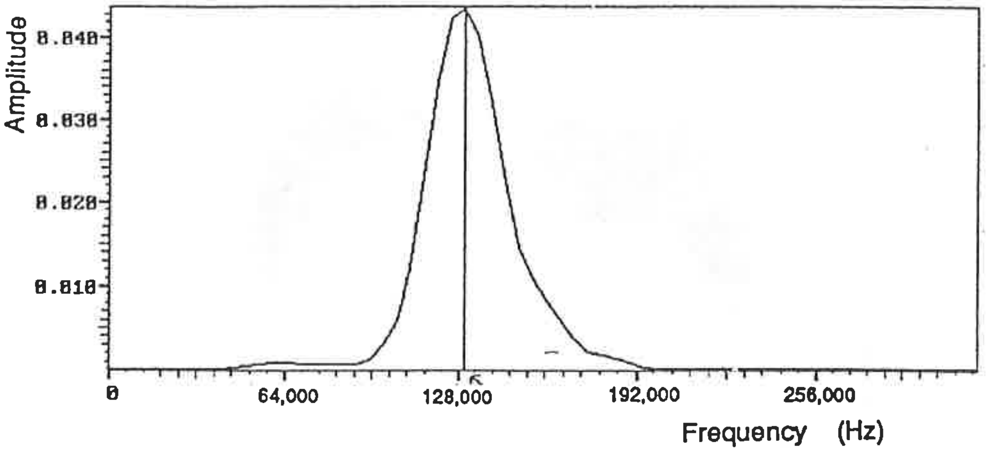


Fig. 1 Spectrum of harbour porpoise click [recording made at 60 ips using Racal Store 141 and replayed for analysis at 15/16 ips (1/64th speed). Frequency peak is at 130 kHz.]

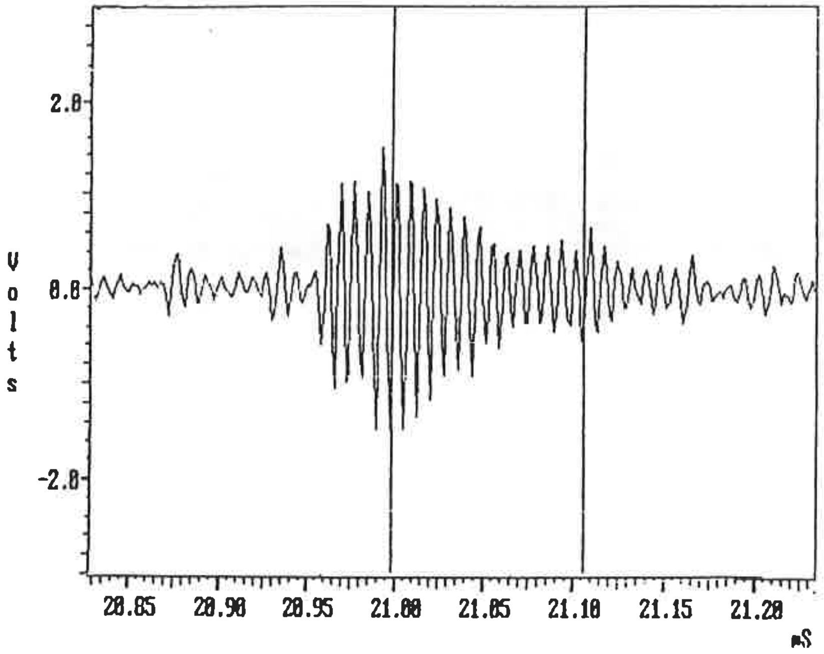


Fig. 2 Waveform of typical harbour porpoise click

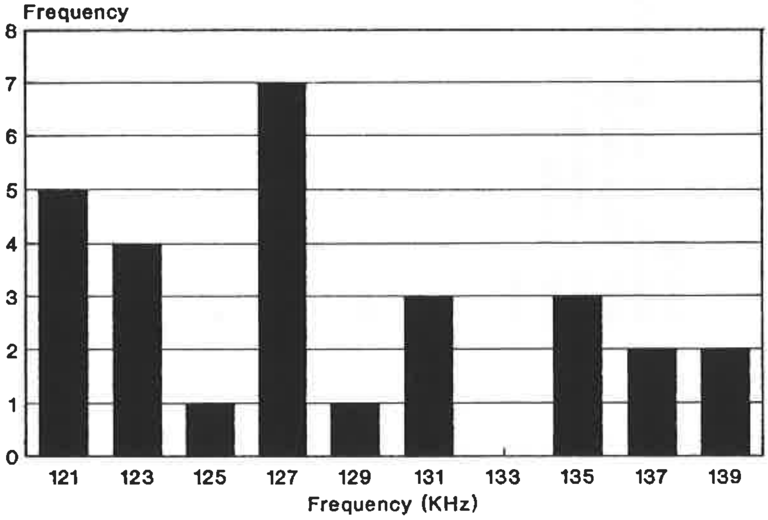
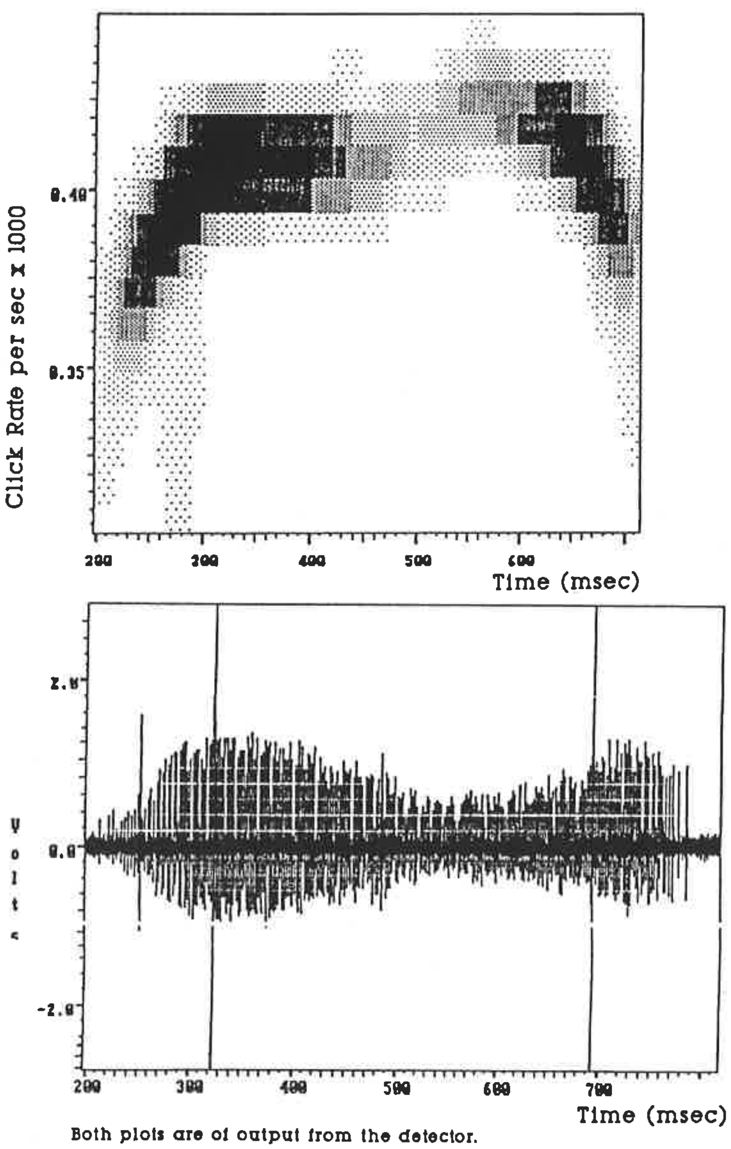


Fig. 3 Distribution of emphasised frequencies measured in harbour porpoise clicks



Both plots are of output from the detector.

Fig. 4 Click rates during harbour porpoise buzz

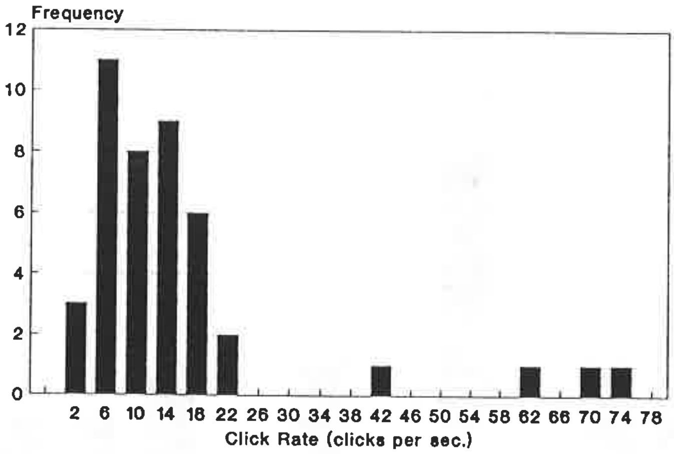


Fig. 5 Rates of clicking during harbour porpoise "slow clicking" vocalisations

BOTTLE-NOSED DOLPHIN SOCIAL ORGANISATION : PERSPECTIVES FROM COLLABORATIVE LONG-TERM STUDIES

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Since 1970, through collaborative efforts of a team of behavioural ecologists, life historians, geneticists, acousticians, physiologists, and veterinarians, we have been able to piece together the basic components of the social organisation of a resident community of bottle-nosed dolphins inhabiting the waters near Sarasota, Florida.

Our primary approach has been to observe individually identifiable dolphins through time. To aid in the interpretation of observational data, capture, sample, mark, and release efforts have provided information on the age, gender, genealogies, and health of many of the local residents. All of the resident dolphins are recognisable, and the ages and sexes of more than 90% are known.

The community consists of about 100 individuals inhabiting a home range of about 125 sq km. Similar communities inhabit adjacent waters, and these share borders, resulting in a mosaic of home ranges along the central west coast of Florida.

At least three generations of residents are currently under observation. To date, our observations indicate that dolphins born into the Sarasota community spend most of their lives within a local society. Patterns of association within this society are based on the sex, age, familial relationships, reproductive condition, and affiliation histories of each of the individuals. Adult females, with their most recent offspring, are found in bands composed of frequent associates who share core areas within the community home range. Associations between members of several maternal lineages within a band may continue over multiple generations. Primiparous females often return to their mother's bands in order to raise their offspring. Close associations between females tend to be tied to their reproductive status.

The period of maternal investment is prolonged. Calves remain with their mothers for 3-6 years. Upon the birth of a new sibling, older calves join groups of juveniles. Adult males swim singly or as members of strongly-bonded male pairs. Pair bonds crystallise at sexual maturity, and may remain intact for at least 17 years. Adult males leave the community home range occasionally, and may serve as vectors for genetic exchange between communities. Different males may sire subsequent offspring of a given female.

AN EXAMINATION OF THE SOCIAL STRUCTURE OF A RESIDENT GROUP OF BOTTLE-NOSED DOLPHINS (*Tursiops truncatus*) IN THE MORAY FIRTH, N.E. SCOTLAND

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INTRODUCTION Bottle-nosed dolphins (*Tursiops truncatus*) live in a wide range of habitats from deep offshore areas to shallow inshore lagoons. In order to do so, members of the species must be both opportunistic and adaptable, and the behaviour patterns of individuals are likely to reflect local environmental conditions. By studying dolphins from a range of different environments we would therefore expect to gain clues as to which environmental factors are responsible for shaping the range of behaviour patterns that we see.

Much is now known about the social organisation of several communities of bottle-nosed dolphins from areas with warm waters and high shark predation pressures, notably those communities using Shark Bay off Western Australia (Connor *et al.*, 1992) and the waters near Sarasota in Florida (Wells *et al.*, 1987). In these areas, calves associated closely with their mothers for their first 3-4 years of life, breeding females belonged to "bands" composed of other closely associated females, and breeding males either swam singly or formed long term bonds ("alliances") with either one or two other adult males.

Our study aims to investigate the social organisation of a community of bottle-nosed dolphins resident in the Moray Firth, Northeast Scotland, where environmental conditions are very different. Here food species differ, predation by sharks appears to be rare if not absent, and water temperatures are relatively low (5-12°C).

METHODS Standardised surveys were carried out in the inner Moray Firth, using a 5m boat with an outboard engine. The survey route covered a 40km long strip following the coastline between Cromarty in the north-east and Inverness in the south-west. Single dolphins or schools sighted were counted, and their location and activities recorded. In addition, photo-identification pictures were taken.

Schools were defined as aggregations of individuals within 100m of each other, engaged in similar activities and, if moving, heading in the same direction.

Calves were defined as small dolphins displaying "foetal folds" (pale vertical bars along their flanks). These bars appeared to last for between 16 to 20 months after birth.

Data examined for this study were collected from 58 surveys made during 1990 and 1991. Over this period around 100 individuals were identified, 84 of which were sufficiently identifiable for inclusion in the following analyses of social structure. Only data where all the individuals in each school were identified were used.

Associations between pairs of individuals from all schools recorded were calculated using the "Simple Ratio Index" (Equation 1). Association values were calculated for all the possible pairings between the 84 individuals selected. These data were then screened for small sample sizes by removing all values where the combined number of sightings of both animals in any pairing (i.e. the denominator in the index) was less than eight.

Equation 1. The simple ratio index: (expressed as a percentage)

$$= \frac{X}{X + Y_{ab} + Y_a + Y_b} \times 100$$

where:

X = Number of observation periods during which animals A and B are observed together.
Y_a = Number of observation periods during which only A was observed.
Y_b = Number of observation periods during which only B was observed.
Y_{ab} = Number of observation periods during which A and B and both observed in separate groups.

RESULTS Schools encountered were generally small with a mean size of 5.9 (ranging from single individuals up to 28).

The calculated association values were plotted against frequency (see Fig. 1). Although there were eight associations above 50 percent, in general values were very low. This would suggest that membership of dolphin schools using the inner Moray Firth was fluid. Indeed, during the study period, 34% of all the 3,486 possible pair combinations were observed.

All of the eight associations above 50 percent were between each of the eight known calves and eight individual adults, which were probably mother-offspring pairs. No associations of greater than 46 percent were observed between any pair of adults.

The associations between fourteen females (adults closely associated with calves) were examined using cluster analysis. A dendrogram, depicting the results, is shown in Fig. 2. This figure represents an inverted hierarchical tree of associations where closely associating individuals are linked by branches to form pairs. The lower the origin of each branch the more closely associated the animals were. These pairs are then linked to the next closest associating animal and so on. In this way, clumps of associating females are built up. Several clumps or "bands" can be seen in the figure. Since all of the links between individuals occur within a relatively narrow band at high levels of distance coefficient, it appears that the structure and distinction between bands is either weak or very subtle.

SUMMARY The structure of bottle-nosed dolphin schools in the inner Moray Firth appears to be fluid, with the only strong associations observed occurring between calves and their probable mothers. A weak structure of banding within adult females was apparent. The robustness of this pattern can be tested by superimposing subsequent years' data to see if the bands observed remain constant. All of the strong associations appeared between calves and their mothers; there was no evidence for the presence of male alliances. This provides a marked contrast with other studies.

ACKNOWLEDGEMENTS This study was funded by the British Ecological Society, the Association for the Study of Animal Behaviour and the Greenpeace Environmental Trust.

REFERENCES

Connor, R.C., Smolker, R.A. and Richards, A.F. 1992. Two levels of alliance formation among male bottlenose dolphins (*Tursiops* sp.). Proc. Natl. Acad. Sci. USA, 89: 987-990

Wells, R.S., Scott, M.D., and Irvine, A.B. 1987. The social structure of free-ranging bottlenose dolphins. Pp 247-305. In *Current Mammalogy*, Vol. 1 (Editor H.H. Genoways). Plenum Press, New York and London.

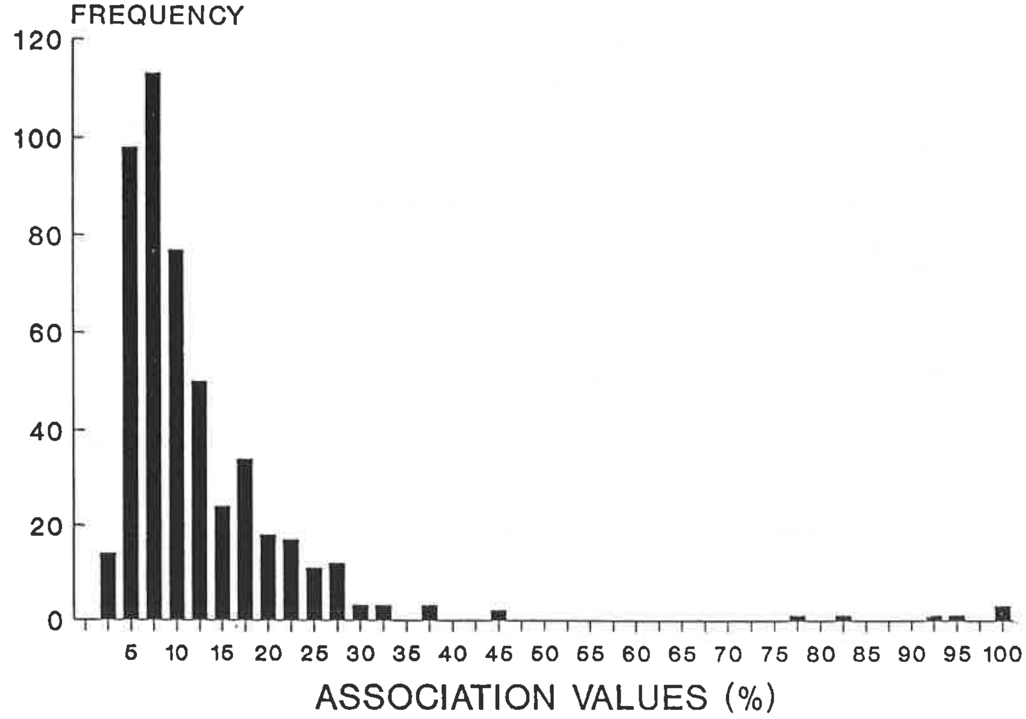

Fig. 1 A frequency distribution of the association values between 84 bottlenose dolphins seen in 1990 and 1991.

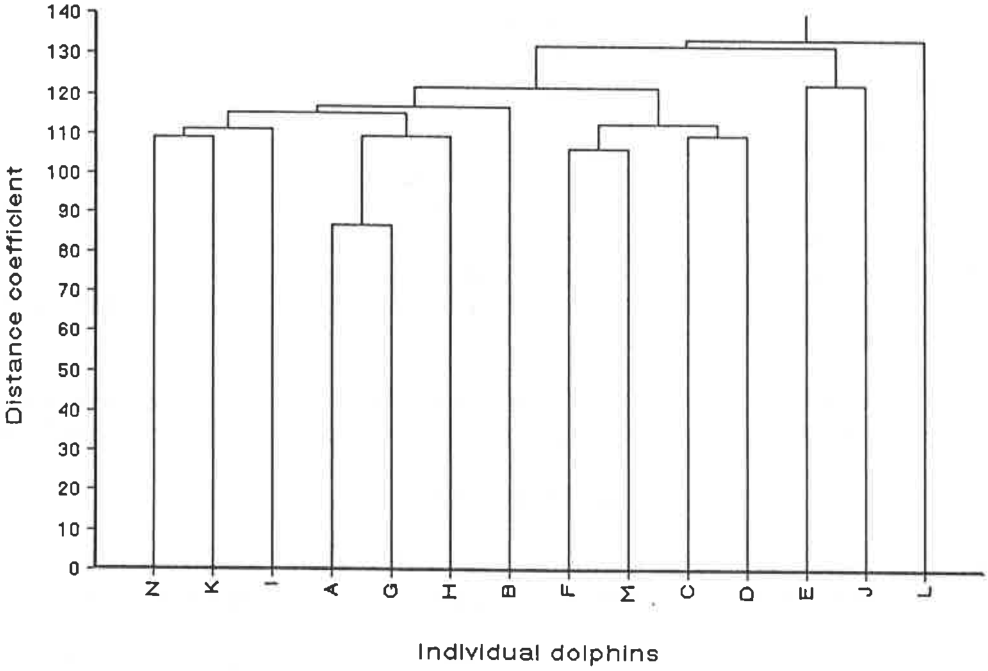

Fig. 2 A dendrogram representing the results from a cluster analysis performed on the association values between 14 female bottlenose dolphins (measure: Euclid; method: single linkage).

COMPARATIVE ECOLOGY OF BOTTLE-NOSED DOLPHINS (*Tursiops truncatus*) IN CARDIGAN BAY AND THE MORAY FIRTH

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INTRODUCTION Several studies of bottle-nosed dolphins (*Tursiops truncatus*) have shown that their behaviour is closely tied to local ecology, and may be expected to vary according to ecological factors (Shane, 1990). Ballance (1990) also has classified marine habitats by physical characteristics, and suggested a relationship between this and local bottle-nosed dolphin population parameters.

For many years, bottle-nosed dolphins have occurred in Cardigan Bay, West Wales and the Moray Firth, North-east Scotland (Evans & Scanlan, 1989). Cardigan Bay forms an open, shallow basin, generally less than 30m in depth in the Irish Sea. It has a few estuaries, small islands, prominent sand banks and rock outcrops (sarns), and receives warm water from the Atlantic. This area of western Britain is popular with tourists who use it for water sports and recreation, operating out of a number of holiday resorts such as Cardigan, Newquay, Aberystwyth and Borth. The Moray Firth lies 800km to the north of Cardigan Bay and is on the north-east coast of Scotland. It has two main estuaries (or firths) which are narrow and drop steeply to 50m, creating strong tide rips. It receives cooler waters from the North Sea. There is an oil terminal at Nigg, near the mouth of the Cromarty Firth, where rigs are also brought for inspection, maintenance and repair. At Fortrose, close to Chanonry Point, recreational activities including water sports may occur in summer.

METHODS We have been studying these two groups of bottle-nosed dolphins since 1989, both from the shore and boat-based research platforms. Dedicated boat transects were conducted in both study areas, following a standardised route and recording procedure. Photo-identification of individuals was carried out during encounters wherever possible. In Cardigan Bay, effort was generally concentrated into the summer months and in the southern portion of the bay between Cardigan and Newquay, although some surveys were made further north, from Aberystwyth and Borth. The Moray Firth received more even coverage both spatially and temporally, with boat transects averaging two per month, in most months of the year. Effort mainly took place over inshore waters between Tarbat Ness at the entrance to the Dornoch Firth, and Chanonry Point in the inner Moray Firth. In both regions, the land-based work was carried out by a number of trained volunteer observers using a similar standardised format, with regular watches through all months.

RESULTS AND DISCUSSION There were several similarities in the behavioural ecology of the two dolphin populations. In both regions, specific localities within the ranges of the dolphins were used to a greater extent than others (see Figures 1 and 2). These areas were characterised by the presence of headlands and/or estuaries, often with relatively strong currents. Land-based observations indicated that in both regions, the numbers of dolphins using inshore waters varied seasonally, peaking primarily between June and August, but with a secondary peak in November and December.

Group sizes differed between the Cardigan Bay and Moray Firth populations in two ways. Groups in Cardigan Bay most commonly numbered between two and five individuals at all times of the year. The secondary peak in observations varied during the year in this population, with a larger number of solitary animals seen in the first quarter of the year, and larger groups (6-10) seen in the last quarter of the year. On the other hand, in the Moray Firth, the groups were frequently far larger than this. Most dolphins seen in the first half of the year were in groups of 6-10 individuals, with maximum group sizes numbering around 40 individuals.

Seasonal variation in dolphin numbers also differed between Cardigan Bay and the Moray Firth. In the Moray Firth, larger groups occurred most frequently in the first quarter of the year and solitary animals were never seen at this time. By contrast, in Cardigan Bay there was a peak in solitary animals during the same period. These differences may be caused by differences between the two regions in the availability of prey species and their seasonal abundance.

A comparison of the frequency of different behaviours recorded indicated that both breaching (CB: 38%; MF: 58% of encounters; $p < 0.01$) and feeding (CB: 57%; MF: 72% of encounters; $p < 0.05$) were observed less frequently in Cardigan Bay than in the Moray Firth. This may also be related to prey species availability and the feeding strategies needed for their capture, since breaching was often associated with feeding. Cardigan Bay dolphins fed alone more frequently than in the Moray Firth, the latter being characterised by larger groups feeding at least sometimes in an apparently co-operative manner. On the other hand, the areas in which feeding predominated in both Cardigan Bay and the Moray Firth were generally near headlands and estuaries (Fig. 3), indicating some similarities in feeding strategies. It may be that fish are more abundant, or that some characteristic of these habitats makes them more preferable for food capture. Tide rips and turbulence are dominant features of headlands which may offer advantages to feeding dolphins. Likewise, estuaries are influenced strongly by tides which tend to channel water in localised areas where it may be easier for dolphins to herd fish prey. Both the Teifi estuary in Cardigan Bay (close to the town of Cardigan), and the Cromarty (between North and South Sutor) and Inner Moray Firths (particularly between Chanonry Point and Fort George) attract quantities of salmon (*Salmo salar*), bass (*Dicentrarchus labrax*) or sea trout (*Salmo trutta*), all of which have been observed as prey for local dolphins.

Approximately 120 individuals were recognised in each of the two regions. No movement of identified individuals between the two areas was recorded. In both populations, the majority of individuals (82 in Cardigan Bay, and 73 in the Moray Firth) were seen only once, and the maximum number of sightings for any one individual was similar (seven in Cardigan Bay and nine in the Moray Firth). This may be due partly to insufficient sampling but also suggests that only a proportion of the population is locally resident, and that there is a fair degree of movement by individuals. An analysis was performed to determine the degree of association between those individuals seen more than once in Cardigan Bay. Groups of animals which associated more frequently with each other than other individuals were identified using a dendrogram of cluster analysis. The only strong associations were between (assumed) mother and calf pairs (Lewis, 1992). For 110 pairwise associations amongst 22 target animals, only fifteen (i.e. 14%) had association values of 50% or more. Those dolphins most frequently seen occurred in each of the two regions for a period of at least two years, indicating a degree of longterm residency. Some of these were observed on several occasions in a localised area over a period of weeks, before apparently moving to another part of the study area.

CONCLUSIONS This comparative study has indicated both similarities and differences between the two dolphin populations which can be related to the local biotic and abiotic environments. Both populations exhibited seasonal variation in abundance. Groups in Cardigan Bay were smaller than those in the Moray Firth and showed different patterns of seasonal variation in group size. Of various activities observed, breaching and feeding occurred less frequently in Cardigan Bay than in the Moray Firth. Such differences in behaviour may be the result of regional differences in prey species availability and abundance. In both regions, the use of waters around headlands and in estuaries may be related to tidally influenced water movements in those areas.

Photo-identification of individuals indicated that only a portion of either population is locally resident, although some animals did show some degree of longterm residency, with sporadic movements between more intensively used areas. The proportion of multiply observed individuals is likely to increase with greater sampling effort.

ACKNOWLEDGEMENTS Funding was generously provided by the Whale and Dolphin Conservation Society, Macdonald and Muir (Glenmorangie Distillery), Frank Stell Scholarship, and Yorkshire Ladies Council for Education. We would like to thank Mick Baines, Steve Hartley, Nick Hughes, Jill Matthews, David, Kenneth & Catriona Meek, and Dai Taylor for their kind hospitality and the services of their vessels; and the dedicated band of local watchers particularly David Galloway, Rachel Harding-Hill, Ben Leyshon, Lyn and Peter Macdonald, Hamish Mackenzie, Jill Matthews, Geoffrey Reading, Sue Warne, and Stuart Wright.

REFERENCES

Ballance, L.T. 1990. Residence patterns, group organisation and surfacing associations of bottlenose dolphins in Kino Bay, Gulf of California, Mexico. Pp. 267-283. In *The Bottlenose Dolphin,* (Eds. S. Leatherwood and R. Reeves). Academic Press, New York. 653 pp.

Evans, P.G.H. and Scanlan, G. 1989. *Historical Review of Cetaceans in British and Irish Waters.* Unpubl. Report to Greenpeace Environmental Trust. 100 pp.

Lewis, E-J. A.M. 1992. *Social cohesion and residency of bottle-nosed dolphins (Tursiops truncatus) in West Wales. An analysis of photographic data.* Unpubl BSc. thesis.

Shane, S.L. 1990. Behaviour and ecology of the bottlenose dolphin at Sanibel Island, Florida. Pp. 245-265. In *The Bottlenose Dolphin.* (Eds. S. Leatherwood and R. Reeves.) Academic Press, New York. 653 pp.

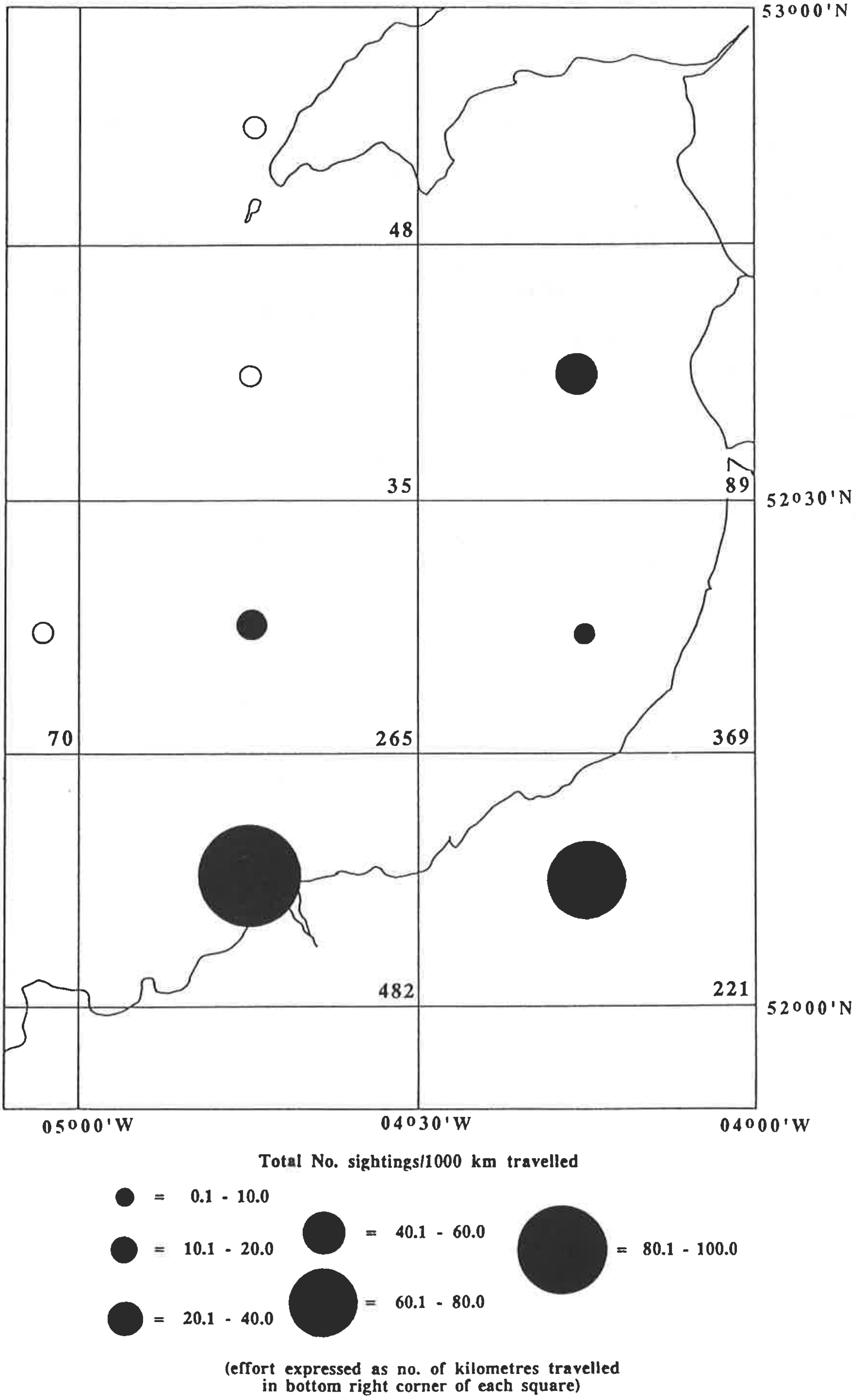

Fig. 1 Distribution of bottle-nosed dolphins in Cardigan Bay, Summers 1990-92 (number of indivs. per 1,000 km travelled on dedicated cruises)

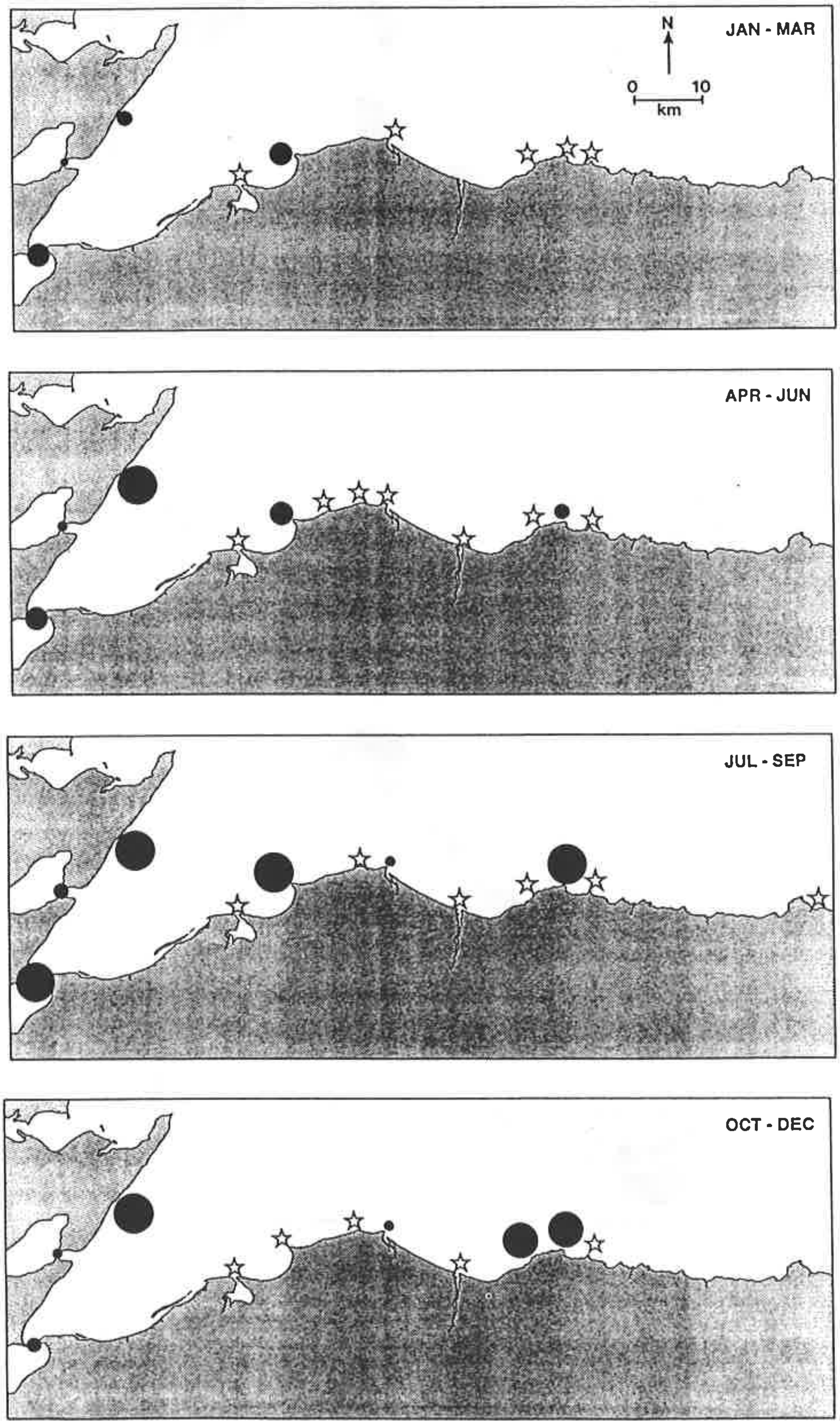

Fig. 2 Seasonal distribution of bottle-nosed dolphins in the Moray Firth and along the Banff coast (from timed watches)

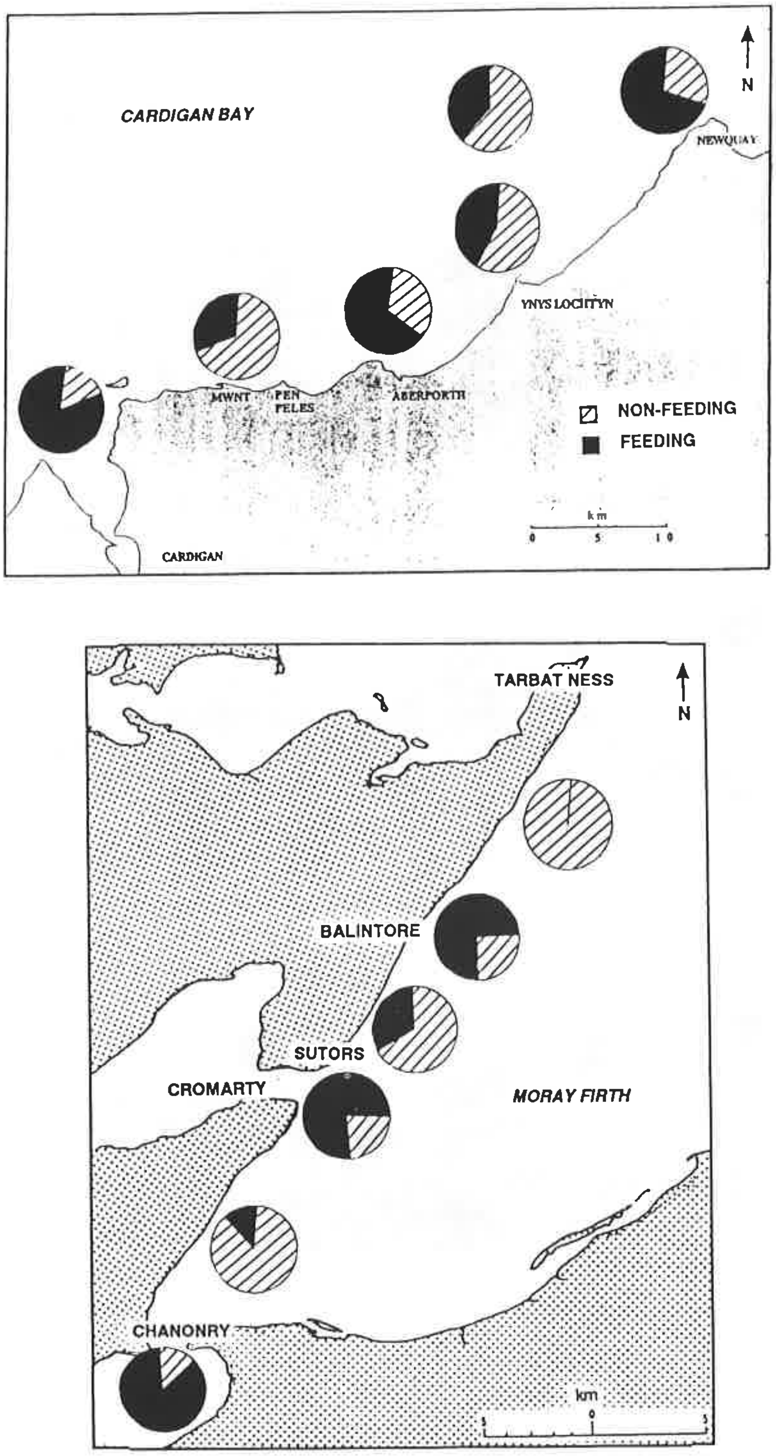

Fig. 3 The presence of feeding bottle-nosed dolphins at locations in (a) Cardigan Bay; and (b) the Moray Firth

DISTRIBUTION, ABUNDANCE, AND HABITAT USE OF BOTTLE-NOSED DOLPHINS IN CARDIGAN BAY, WALES, 1992

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INTRODUCTION One of the best known populations of bottle-nosed dolphins (*Tursiops truncatus*) in British waters is found in Cardigan Bay off the west coast of Wales. Following their pilot photo-identification study in 1990, Greenpeace UK continued systematic studies from Aberaeron to Cardigan Island between April and December 1991 and in January and April 1992, resulting in the identification of 107 individual dolphins. This study builds up on the data collected by Greenpeace, with the aims of assessing bottle-nosed dolphin abundance, distribution, and habitat use, and the prevalence of skin lesions for comparison with the situation in the Moray Firth.

METHODS Surveys were conducted at least twice monthly from a 10 m fishing boat between July and November 1992, along pre-determined transects covering a 35 km length of coast from Aberaeron to the Teifi Estuary. Ten full and five partial surveys were made in this 'standard survey area' at distances of 2-6 km from the shoreline. Three surveys were also run to Sarn Badrig and Bardsey Island in the north of the bay, as well as three inshore trips covering the coastline south of the Teifi Estuary to St David's Head and Grassholm. Photo-identification of individual animals was carried out from photographs using natural markings including nicks, rakes and de-pigmentation of their dorsal fins, back and flanks. These photographs were taken with an autofocus camera fitted with a 75-300 mm zoom lens. Environmental data were collected during each encounter with dolphins, as well as details of group size, location and behaviour. Similar data were recorded for sightings of harbour porpoises (*Phocoena phocoena*). The preliminary results presented here include all data collected in 1992.

RESULTS

Abundance In 1992, between 80 and 101 individual dolphins were identified, including 36 to 57 new animals and 44 individuals known from previous years. The minimum estimate for the number of bottle-nosed dolphins resident in or passing through Cardigan Bay is therefore 80 animals. The greatest number of new individuals were identified in October (Fig. 1) which may indicate an influx of animals into the bay in late autumn. Sixteen dolphins have been re-sighted in each of the past three years and 70 animals (43% of all identified individuals) have been photographed only once, despite a number of them bearing distinctive markings.

Group Size and Composition All of the dolphins visible during an encounter within a 100-200m range of each other and displaying similar or related behaviours were considered as one group. Group size ranged from 1-30 animals wth mean group size peaking at thirteen individuals in October. The pattern of group size distribution in 1992 was similar to that found in 1990 and 1991, with small groups of 2-6 individuals being the most common (see Fig 2).

Calves were present in dolphin groups in 60% of all encounters. Two calves from 1991 were re-sighted and five females with calves born in 1992 were identified. Two of the calves appeared to be very young. One was first seen at the end of July; the most recent sighting of its mother prior to this was in April accompanied by an older calf. The other young calf and the female accompanying it were both first identified at the end of September 1992.

Distribution A total of 115 hours was spent searching in the standard survey area. Although search time throughout the bay totalled 166 hours, dolphins were observed only 25% of that time and encounters occurred only in the area of the standard survey between Aberaeron and the Teifi Estuary (Fig. 3). The majority of encounters (83%) were within 4 km of the coast, frequently near or inshore of the 20m contour. Dolphins appeared mainly off headlands from New Quay to Ynys Lochtyn, Aberporth and Pen Peles, and in the bay-like regions of New Quay Harbour, Aberporth Bay and the Teifi Estuary. Feeding activity was noted during 74% of encounters, often inshore in depths of less than 20m. Harbour porpoises were more widely distributed from Pen Bwch Point north of Tywyn to Strumble Head in the south of bay (Fig.4).

Skin Lesions A variety of skin lesions were photographed and the data are being analysed. Some skin conditions appear similar to those found in the Moray Firth bottle-nosed dolphins and we aim to compare the prevalence of lesions in the two populations.

CONCLUSIONS Some 30% of the total survey effort extended to the northern and southern coasts of Cardigan Bay, but dolphins were observed only in the vicinity of the standard survey area. The main sites of dolphin activity were off headlands and in sheltered shallow bays. The sixteen animals seen in 1990, 1991 and 1992 were photographed throughout the standard survey area and no site fidelity or territoriality is yet evident. Feeding was the primary activity observed and the dolphins have been seen eating or chasing a variety of fish including clupeids, mullids, salmonids, scombrids and serranids.

Bottle-nosed dolphins are also seen occasionally off Aberystwyth, Tywyn, Bardsey and along the Lleyn Peninsula to Anglesey. Future studies aim to include systematic surveys of the entire bay to obtain a more complete picture of the range of these animals. However, the distribution of dolphin groups, re-appearance of known individuals, frequent presence of calves and repeated feeding activity all suggest that the coast between New Quay and the Teifi Estuary is an important area for the bottle-nosed dolphins resident in or passing through Cardigan Bay.

ACKNOWLEDGEMENTS This study was funded by the Greenpeace Environmental Trust. Thanks are also due to Dr. Sue Mayer and Greenpeace UK for providing their data as the basis for this study. I am also particularly grateful to the following for their help with logistic support; Steve Hartley, Dave Thomas, Mick Green and other Friends of Cardigan Bay, Mick Baines and the Dyfed Wildlife Trust Seal Survey Team, and the Countryside Council for Wales.

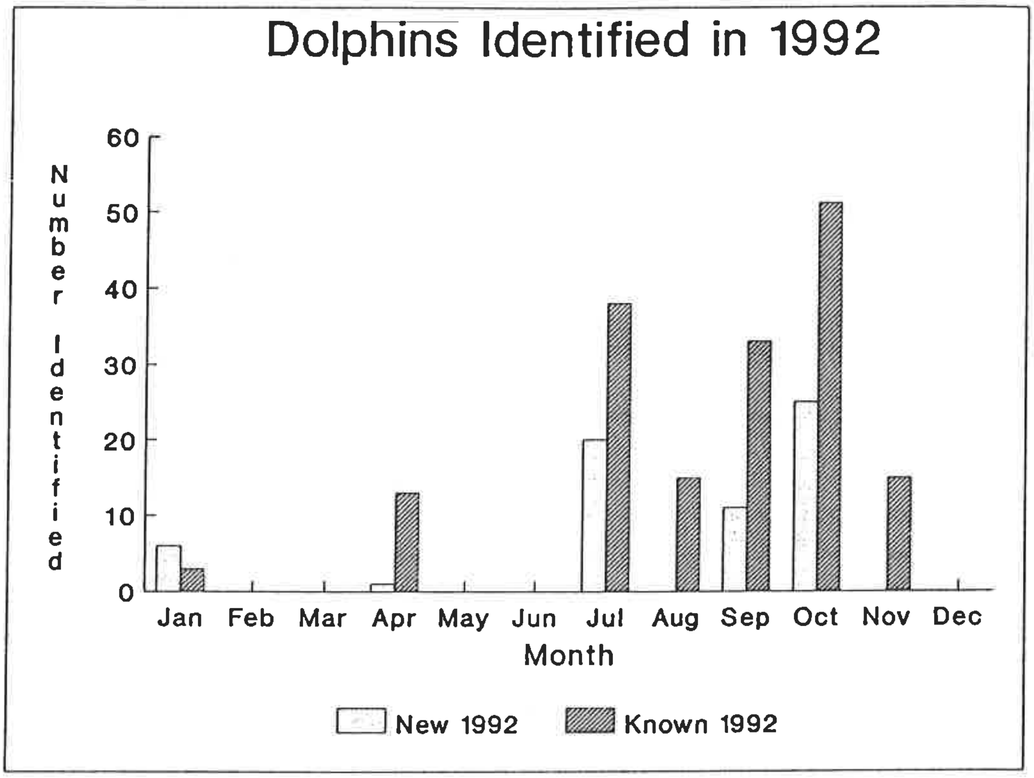

Fig. 1 New and re-sighted dolphins identified in 1992.

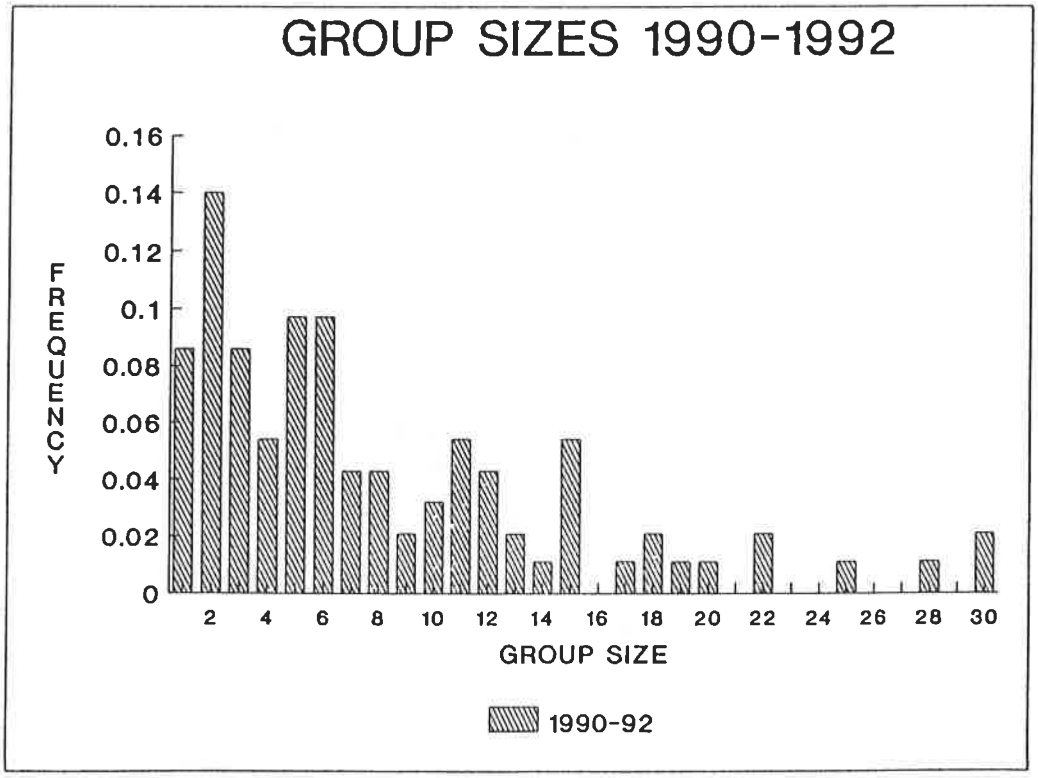

Fig.2 Frequency distribution of dolphin group sizes 1990-1992.

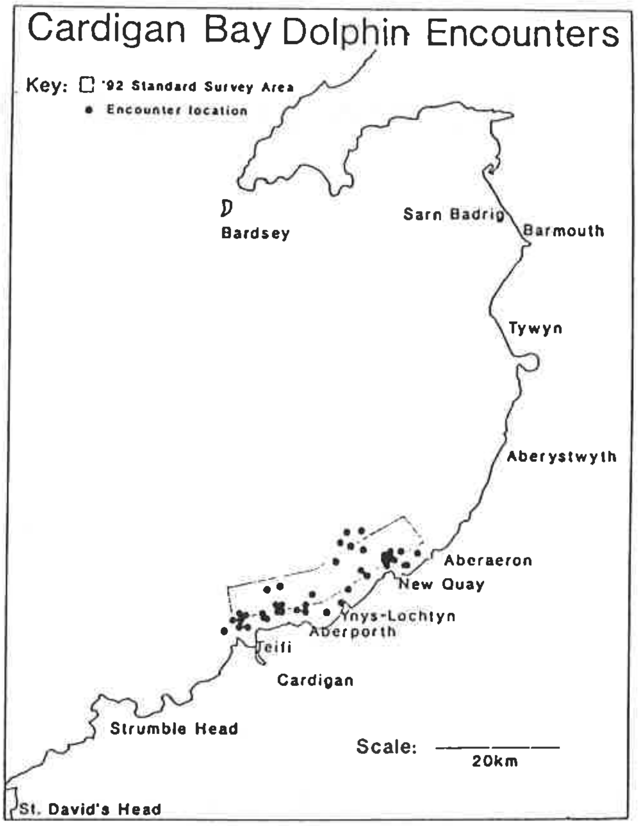

Fig.3 Location of dolphin encounters in 1992.

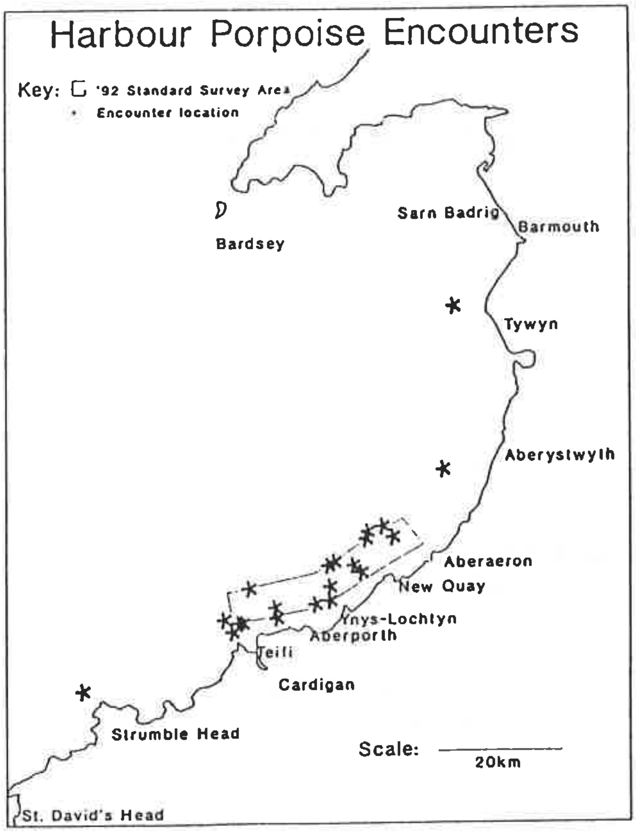

Fig.4 Location of harbour porpoise encounters in 1992.

THE MOVEMENTS AND ACTIVITY TIME BUDGET OF A WILD, SOLITARY, BOTTLE-NOSED DOLPHIN (*Tursiops truncatus*) MONITORED THROUGH COMPLETE 24 HOUR CYCLES.

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INTRODUCTION The subject animal, a mature male bottle-nosed dolphin (*Tursiops truncatus*) (called Freddie), was resident off the Northumberland coast of England from April 1987 to February 1992. The limits of this animal's established home range spanned less than 0.5km^2 (Bloom, 1991) and were visible from the harbour mouth making continuous observations possible. the river Coquet, which enters the sea at Amble, flows through a narrow harbour entrance and this zone served as the focus for foraging activity (see Fig.1).

MATERIALS AND METHODS Observers and equipment, based both on the South pier and in a mobile home at the landward end of the pier montored this animal at close range without modifying its normal behaviour patterns. Six intensive 24 hour watches were completed (June '89, January '90, June '90, January '91, June '91, and January '92) using the same nucleus of researchers for each watch. The research team employed both visual and underwater acoustic monitoring techniques.

Acoustic data were recorded from B & K 8104, Sonar International D170 and D300 hydrophones via telemetry links on either a Wideband Racal Store 4DS or Nagra IV-S or IV-SJ recorders. Hydrophones were deployed with most success when attached with pre-amp to an endless loop anchored 50m beyond the pier but with the sonobuoy staying on the pier. For sewer buoy deployment, a wide band sonobuoy (with its hydrophone depth modified for mid-water) was fixed between an anchored float and the sewer buoy.

Visual sightings data were logged onto voice tapes and pre-printed record sheets. A video camera was also employed when conditions allowed. A communications receiver, tuned to the radio telemetry frequency, helped match visual and acoustic observations. Hand-held VHF transceivers provided communications and co-ordination between pierhead, boat handler and base, and also allowed observer commentary to be recorded simultaneously onto the Racal recorder at base. This operation ran best with six observers working two at a time on a shift system at the pierhead with two or three technical operators using a similar shift arrangement in base station. The base vehicle was required for housing the mains powered recording and monitoring equipment which could not function well at the seaward end of the pier.

OBJECTIVES The objectives of the watches were to record the movements of the dolphin around his home range and accumlate data on his apparent behaviour through the complete 24-hour cycle using a standardised method. The accumulated data could then be compared wth other similar systematic watches and also provided a useful guide to the accuracy and interpretation of casual watch data. When conditons allowed, the movements of the dolphin were logged in the different designated areas of his home range. These were: (1) Harbour mouth; (2) Wreck; (3) Pan Bush; (4) Sewer buoy; (5) Post.

At times when poor light or sea conditions made constant tracking difficult, each individual sighting and its position were recorded. For analysis of behaviour, the 24 hours were split into 96 fifteen-minute watch periods. When identifiable, the apparent activities of the dolphin were also recorded for each of these fifteen-minute periods, where possible using both acoustic and visual data. Relevant environmental data was logged, such as weather, sea state, visibility and tidal state as well as boat traffic and swimmer activity, and the dolphin's apparent reactions to these events. The activities of the dolphin being monitored were: (1) Forage; (2) Resting; (3) Recreation.

The geographic location of Amble (55°20'N) results in a seasonal variation in daylength of approximately 10 hours. The original watch was scheduled for late June to maximise daylight duration. A midweek time was also chosen to try to reduce the frequency of recreational swimmers and boat interference. To reverse the daylight hour bias, the second watch was scheduled for mid-winter.

RESULTS

Home Range Time Budget During the six watches conducted, the dolphin spent half of his time in the harbour mouth (49%), just under a quarter of his time at the sewer outfall buoy (23%) (situated 500 metres to eastward of the harbour entrance), and a further 12% in the other areas of his home range. During the remaining 16% of the total 144 hours, the dolphin was neither visually nor acoustically monitored. Most of this lost time coincided with the long winter night periods when the dolphin moved away from the harbour mouth. The dolphin was observed to leave the home range on only two occasions which accounted for just 0.5% of the total watch time. Both excursions were for boat escort duties (see Fig. 2).

Tidal Influence on Home Range Use Tidal rhythms appeared to be the major influence affecting the dolphin both directly due to water depth variations, and indirectly due to effects on prey behaviour. Analysis of the dolphin's location during the four tidal phases showed a very strong preference for the harbour mouth area during the ebb tide flow phase (81%). Much of the dolphin's time was also spent in the harbour mouth during flood flow (36%) and high water slack tide phases (43%). However , the dolphin was also recorded regularly at the sewer buoy during these phases (30% flood and 28% high) so his location during these two phases were less predictable. During low water slack tide, when water levels in the harbour entrance were often less than two metres, the dolphin was most often recorded in the sewer outfall buoy area (33%). During summer watches (with their much longer daylengths) sewer buoy residency accounted for half (51%) of low water slack tide time, so the total figure for sewer buoy residency of 33% is perhaps an underestimate (see Fig. 3).

Dolphin activity For analysis of dolphin activity, the 24 hours was split into 96 fifteen minute watch periods (WP's) and the defined activities of 'forage', 'resting' and 'recreation' recorded (see Fig. 4).

Forage activity was most often associated with the harbour mouth area, especially at night during the ebb tide phase and was also recorded more often during the winter watches. Foraging, unlike the other defined activities, was monitorable at night because of its distinctive acoustic characteristics and was recorded on 51% of occasions (293 of 576 WP's but 61% of known activity, i.e. 293 of 478 WP's). When diurnal WP's only were considered, the proportion of time spent foraging declined to 42% (149 of 356 daylight WP's).

Resting was most often associated with the sewer buoy area during low water tidal phase but there was no apparent seasonal effect. This behaviour was only monitorable visually because there was no apparent acoustic component. This suggests that the diurnal WP ratio (36%) is a more representative indicator of the frequency of occurrence of this activity rather than the 22% for total and 27% for known WP's.

Recreational activity defined for the purposes of this study as close association with boats and swimmers, was dependent on such opportunities. It could develop at any time and could draw the dolphin to any part of his home range. This activity was most evident during flood flow and high water slack tide, but there was little apparent tidal or seasonal effect. This activity was occasionally recorded during nocturnal WP's (8%), but only if the event took place close to the observer position on the pier, suggesting that this activity is also best represented as the higher daylight ratio of 34% rather than the 22% of total and 27% of known WP's. Recreational opportunities occurred in 194 WP's, with the activity actually developing in 62% of these.

Movements During the 356 diurnal WP's, the dolphin's travel movements could be accurately monitored. In 142 WP's, an inter-area movement was recorded, 62% (88) of which were recreationally motivated, usually as a result of boat escort duties. During one non-boat related movement, the dolphin was observed to travel a distance of approximately 450 metres, from sewer buoy to harbour mouth area, in 45 seconds, giving an average travel speed of 36 km/h.

CONCLUSIONS With only six watches, it is accepted that it is difficult to draw any solid conclusions. Nevertheless, this dolphin has provided an interesting insight into the time budget and activities of a wild dolphin throughout complete 24 hour cycles.

Foraging, the dominant activity, was recorded in over half of the total watch periods. However, comparison of forage data, derived purely from visual or acoustic monitoring techniques, suggests that, although the sole use of visual observations may accurately monitor forage activity, it is a much poorer indicator of actual hunting events. Ideally a combination of both methods should be used to complement each other. This study also suggests that purely diurnal watches may under-estimate the amount of time and effort devoted to forage activity

Steady echolocation click train activity was the principal fish detection and hunting tool, most commonly used in conjunction with a regular patrol pattern. Conversely, when travelling between different areas of his home range, echo-location activity did not appear to play a major role in navigation of known territory. Prolonged acoustical coverage in the dolphin's principal 'resting' area at the sewer buoy indicated that this was a silent behaviour.

Finally, six weeks after the last winter watch included in this paper, the dolphin changed his lifestyle dramatically by disappearing from his home range completely. During the following weeks there were occasional sightings up and down the coast to the south, before the final confirmed sighting on 26 April 1992 at Roker pier, Sunderland (Bloom, unpubl.).

ACKNOWLEDGEMENTS I thank Eurogroup for Animal Welfare, and Dolphin Services (Bloom UK) for financial support; the following who regularly participated in the watches: Dr. Margaret Klinowska, David Goodson, Bill Prickett, Chris Sturtivant, and those others who contributed in one way or the other on some of the watches: Roger Mayo, Brian Woodward, Emily Lewis, Geoff Ellis, Ben Wilson, Michel van Hove, Steve Walton, Dave Lindsey, Penny Gersch, Sophie Rodrick, John Moran, Sue Owen, Kate Cole, Lesley Hunter, Dave Maddocks, and Margaret Watson. Gordon Easton, Dave Grey, Dave Bone, Peter Watson and Stuart Barnes all provided boat coverage. Brenda and Jim Henderson provided accommodation and meals at the Harbour Guesthouse. Lesley Hunter and Dave Maddocks of HM Associates donated computer time and graphics generation.

REFERENCE

Bloom, P.R.S. (1991). The diary of a wild, solitary, bottle-nosed dolphin *(Tursiops truncatus)* resident off Amble on the north Northumberland coast of England, from 1987 to January 1991. Aquatic Mammals, 17 (3).

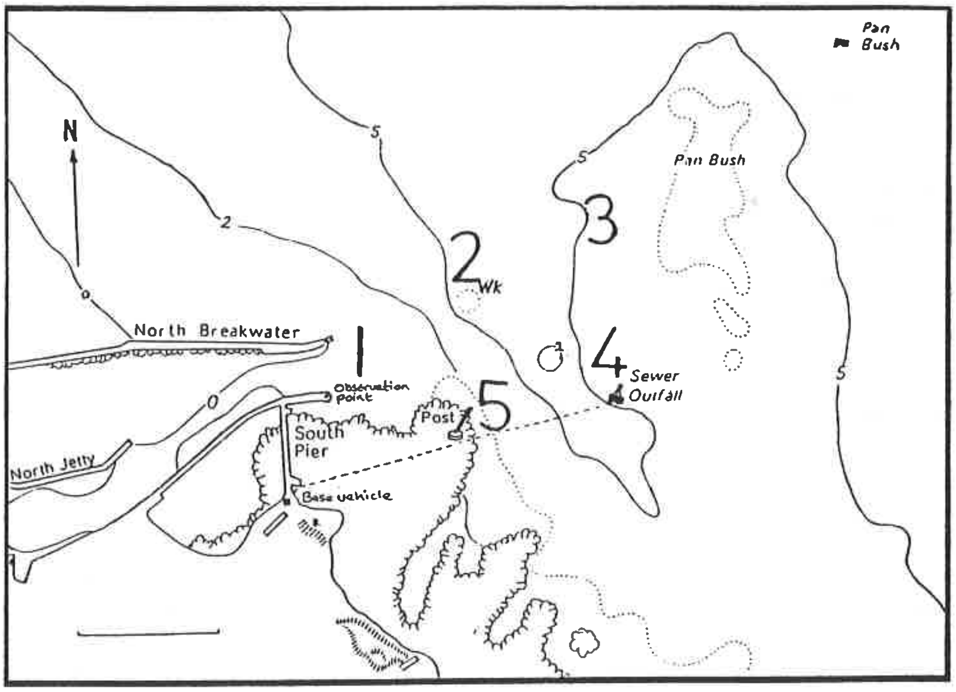

Fig 1 Occurrence of dolphin activities

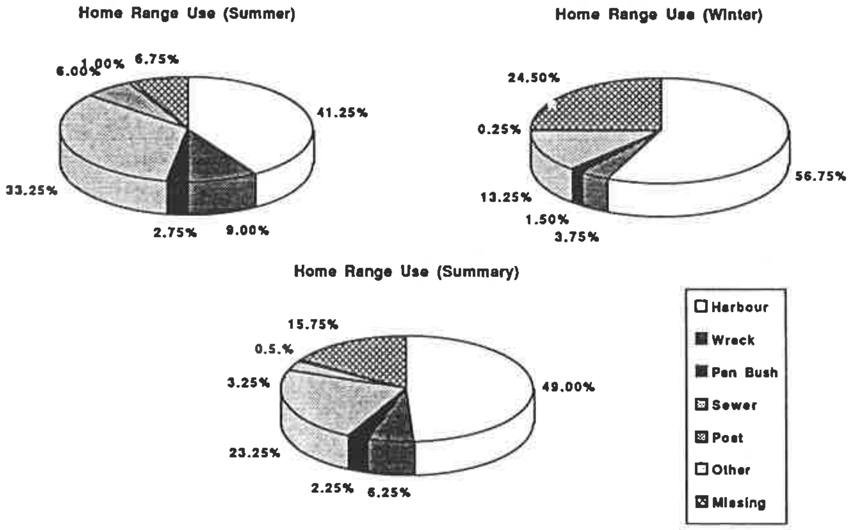

Fig 2 Home range use time budget

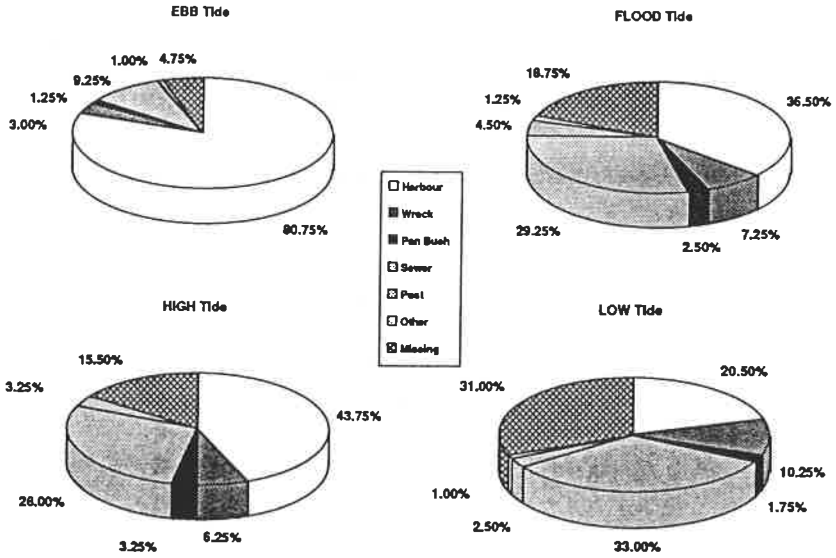

Fig 3 Tidal influence on time budget

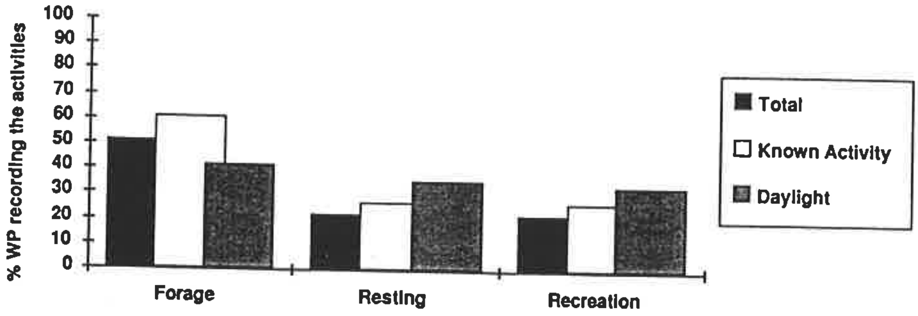

Fig 4 WP and occurrence of dolphin activity

BOTTLE-NOSED DOLPHINS (*Tursiops truncatus*) IN WESTERN BRITTANY

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The status and the behavioural ecology of the bottle-nosed dolphin (*Tursiops truncatus*) in Western Brittany (Iroise Sea) was studied over a 14 month period.

Bottle-nosed dolphins are observed on a year round basis in the vicinity of two localities, one at Sein Island and the other one at Molène Archipelago.

Fourteen dolphins have been photo-identified at Sein Island. The size of the group off Molène Archipelago is estimated to be close to 30 dolphins from a capture-recapture method applied on the photographic database but also from counts done on aerial footage available. Until now no exchange between these two localities has been recorded.

The activity and spatial distribution of bottle-nosed dolphins off Molène Archipelago were monitored through the summer. Five main activity classes (fishing, travel, rest, social interaction and boat interaction) subdivided in ten subtypes were discriminated using speed, change of direction, and surface activity. At Molène Archipelago, dolphins spent 33% of their time fishing, 32% resting, 22% travelling, 8% in social interaction and 6% on boat interaction mostly observed with the research boat. The impact of boating activity on the dolphins in the archipelago remains at a very low level. The home range covered 70.5 km^2 but dolphins tended to concentrate their activities in a smaller part of their range.

At Sein Island, dolphins concentrated the fishing activity in a limited portion of their range. Off Sein Island, we initiated a four-year research programme to study the spatial and temporal distribution of bottle-nosed dolphins in relation to prey availability. One of the most common feeding behaviour observed was to fish against the tidal current. In the study site, dolphins were almost exclusively observed fishing when the tide was rising. To investgate if the occurrence of dolphins and prey availability was motivated by a higher foraging efficiency, we monitored the change in prey availability. The speed of the current was recorded and fish were counted using an underwater video camera. Preliminary results indicate that the foraging efficiency is likely to be improved when the tide is rising, as fish is more abundant while swimming costs are identical at either rising or ebbing tide. Furthermore, while monitoring fish abundance, underwater footage of hunting dolphins was obtained.

SURFACING PATTERNS OF BOTTLE-NOSED DOLPHINS IN THE CRES-LOSINJ AREA (NORTHERN ADRIATIC SEA)

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INTRODUCTION Würsig *et al.* (1984), working on bowhead whales, pointed out that "breathing patterns may differ during different behaviours and activity levels and may be useful in characterising such behavioural states". They also assumed that "the rate of visible blowing is a useful and quantitive measure of behavioural state. On the other hand, most behavioural studies conducted on bottle-nosed dolphins (*Tursiops truncatus*) focused on the dolphin's movement, relative position, and aerial performances such as leaps, fish tosses, etc. (Shane *et al.*, 1986; dos Santos and Lacerda, 1987; Hanson, 1990; Shane, 1990; Ballance, 1992), while a consistent recording of dive duration was not used as a primary source of information. In this paper, we tested the use of dive data as a primary and non-subjective tool for definition of and discrimination between various behavioural states.

MATERIALS AND METHODS The study area, adjacent to the islands of Losinj and Cres (Northern Adriatic Sea) covers approximately 900km^2. The underwater topography ranges from rocky shallows, sea grass flats, and muddy bottoms at a depth of 60-80m. Observations were conducted from a Novamarine 2, 4.6m inflatable craft with fibreglass keel, equipped with a Honda 4 strikes, 45 HP outboard engine. Observations were focused on the most recognisable animal within the group, referring to that animal as a *focal individual* (Altmann, 1974). We used a portable tape recorder with 100-minute cassettes for field work. The tape ran continuously and when a surfacing occurred, it was recorded on tape. All the surfacings were considered as instantaneous respiratory events, although we could not always be sure that the dolphin breathed every time it surfaced. To reduce biases due to the timing of different animals, we interrupted the sample every time we were not completely sure of assigning a surfacing to the focal individual. The surfacings were then timed from the cassette with the help of a digital stopwatch.

In order to analyse the dive times within a behavioural context, we continuously observed the focal dolphin activity for successive periods of 3 min. This "instantaneous sampling method was chosen, following Shane (1990). To avoid any personal interpretation of functional meaning of the behaviour, we used only three objective parameters for the defintion of the dolphins activity: (1) duration of the dives; (2) presence/absence of steady directional movement; and (3) presence/absence of trawling boats.

The 30 sec value was chosen, according to dos Santos *et al.* (1990), as an adequate value for discriminating between dives likely to be simple ventilations, and long dives. Dives were defined as "short" if lasting 30 sec or less, and "long" if exceeding 30 sec.

The behaviour of the focal dolphin was therefore defined as follows;
-"Dive" (D), if the dolphin performed at least one long dive during the 3 min sample, remaining in the same area without steady directional movement.
-"Dive/travel" (DT), if the dolphin performed at least one long dive during the three-minute sample, travelling in a steady direction.
-"Following of fishing boat" (FB), if the dolphin performed long dives in the wake of a fishing boat engaged in trawling activities.

All the activities which did not involve long dives were placed in a separate category, labelled "other".

RESULTS AND DISCUSSION The surfacing samples were collected during a total of thirteen surveys conducted from 9 August through 10 September, 1992. Twenty-two continuous samples of dolphin surfacings, totalling 1,109 submergences were obtained for six different focal individuals. The samples ranged from 10 to 60 minutes, for a total of 7h 23 min.

The duration of the submergences ranged from 4 sec to 4 min 41 sec, the mean duration being 24.0 sec (SD = 33.09, SE = 0.99). The mode was 10 sec; there was little difference in the modal duration of the dives for the six individuals sampled, the modal value ranging fron 8 to 10 sec. 85% of the submergences recorded, lasted less than 30 sec.

In order to analyse the submergences within the behavioural context of occurrence, we separated the dive data recorded during different activity samples. In this study we focused on activities involving long dives, which are probably related to both exploratory and feeding behaviour. "Dive" (D), "Dive/Travel" (D), and "Following of fishing boat" (FB) were therefore considered as behavioural states, while the category labelled as "other", encompassing every activity characterised by short dives, was not analysed because of its high behavioural heterogeneity. A total of 949 submergences related to 3 min samples including long dives. "D" presented the highest mean: 32.8 sec ± 43.22 SD (n=118), with a modal value of 9 sec. "D/T" and "FB" had lower means, respectively of 25.1 sec ± 29.18 SD (n=575), and 23.6 sec ± 43.04 SD (n-256), with a mode of 10 sec. The frequency distribution of duration of submergences for "D", "DT", and "FB", divided into 100 intervals with an interval of three seconds, is shown in Figure 1. The frequency distribution is similar on the left side of the graphs, but on the right side it exhibits a different pattern. A Kruskal-Wallis test showed a significance in the distribution of the variables (H=26.9, df=2, P<0.001), the differences being highly significant between FB and both DT and D (Dunn's multiple comparisons).

In order to investigate the possible meaning of this difference, we arbitrarily chose the value of 30 sec, already used to descriminate between different activities, and for dividing "long" and "short" dives within the same activity. During the "Following of fishing boats" dolphins perform only a few "long" dives (9% of the total) of considerable length (mean = 2 min 19 sec), but many (81%) "short" dives (mean = 12.8 secs). During "Dive", the frequency of the "long" dives is higher (24%), but the mean duration only 1 min 36 sec, while the mean duration of "short"dives is 13.2sec. During "Dive/Travel", the mean duration of the "long" dives (18% of the total) is also low (mean = 1 min 13 sec), while "short" dives present the highest mean (14.6sec). Descriptive statistics on long and short dives is presented in Table 1.

The mean duration of the short dives was tested with an analysis of variance (F=8.18, df=2, P<0.001), the difference being significant between FB and DT (Tuckey's q=3.77, P<0.05). With respect to long dives, a Kruskal-Wallis test was performed because of the heterogeneity of the population variances. The durations of the dives were significantly different (H=13.2, df=2, P<0.001), and Dunn's multiple comparisons showed differences between D and DT, and FB and DT.

A larger sample would be required for defining the typical pattern of each behavioural state in terms of surfacing sequence. The influence of many temporal and ecological factors (such as season, year, water depth and temperature, bottom type, prey species, etc.) should also be considered. Nevertheless, this preliminary study shows that different behavioural states are characterised by different surfacing patterns, and that the mean duration of the long and short dives could provide useful insights for the understanding of the underwater activity of the dolphins.

ACKNOWLEDGEMENTS Eleni Politi assisted in data gathering and data analysis. Insightful comments were made by Guiseppe Notarbartolo di Sciara. Financial support and donations of equipment were received from Europe Conservation, Novamarine 2, and Patagonia Italy. We are grateful to the Island Development Center and the Commune of the Cres-Losinj for local assistance.

REFERENCES

Altmann, J. 1974. Observational study of behaviour: sampling methods. Behaviour, 49(3-4): 227-267.

Ballance, L.T. 1992. Habitat use patterns and ranges of the bottlenose dolphin in the Gulf of California, Mexico. Mar. Mamm. Sci., 8(3): 262-274.

Dos Santos, M.E. and Lacerda, M. 1987. Preliminary observations of the bottlenose dolphin *(Tursiops truncatus)* in the Sado Estuary, Portugal. Aquatic Mammals, 13(2): 65-80.

Dos Santos, M.E., Xavier, P., and Lazaro, A. 1990. Measuring surfacing intervals in free-randing bottle-nosed dolphins. Pp. 82-85. In *European Research on Cetaceans - 4*: (Eds. P.G.H. Evans, A. Aguilar and C. Smeenk). Proc. 4th Ann. Conf. ECS, 2-4 March 1990, Palma de Mallorca. European Cetacean Society, Cambridge, England.

Hanson, M.T. 1990. *The behaviour and ecology of Pacific Coast bottlenose dolphins.* Master Thesis, San Diego State University. 116 pp.

Shane, S.H. 1990. Behaviour and ecology of the bottlenose dolphin at Sanibel Island, Florida. Pp. 245-265. In *The bottlenose dolphin.* (Eds. S. Leatherwood and R.R. Reeves). Academic Press, San Diego. 653 pp.

Shane, S.H., Wells, R.S. and Würsig, B. 1986. Ecology, behaviour and social organisation of the bottlenose dolphin: a review. Mar. Mamm. Sci., 2(1): 34-63.

Würsig, B., Dorsey, E.M., Fraker, M.A., Payne, R.S., Richardson, W.J., and Wells, R.S. 1984. Behaviour of bowhead whales, *Balaena mysticetus*, summering in the Beaufort Sea:surfacing, respiration, and dive characteristics. Can. J. Zool., 62: 1910-21.

Table 1: Descriptive statistics for long and short dives;
s.d. = standard deviation, s.e. = standard error.

	Activity	n	X	s.d.	s.e.
Short dives (< 30 sec)	**D**	90	13.2	5.19	0.55
	DT	472	14.6	6.13	0.28
	FB	234	12.8	5.69	0.37
Long dives (> 30 sec)	**D**	28	96.0	50.72	9.59
	DT	103	73.1	42.14	4.15
	FB	22	139.1	82.73	17.64

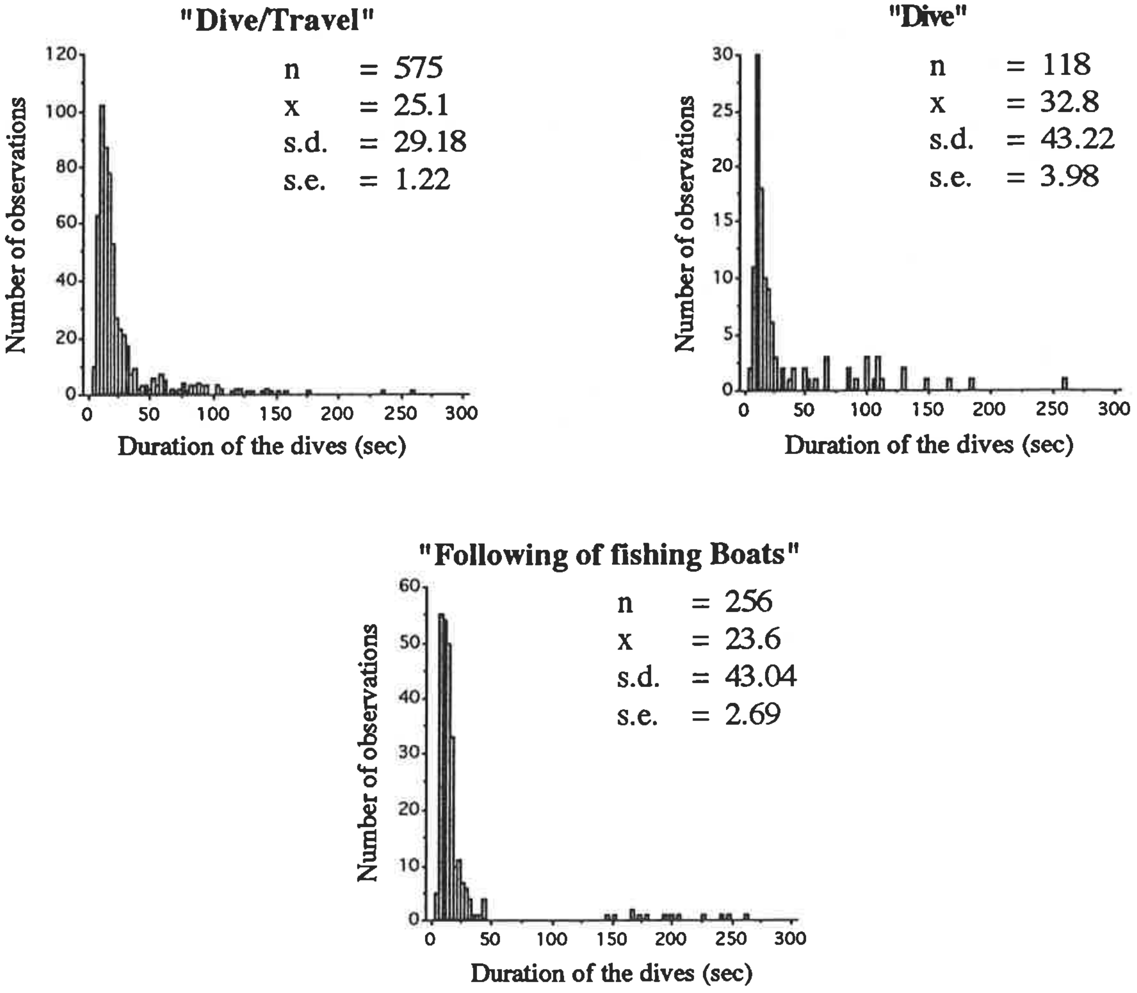

Fig. 1: Frequency distributions of the dives' duration for the three behavioural activities considered; s.d. = standard deviation, s.e. = standard error.

BEHAVIOUR OF STRIPED DOLPHINS (*Stenella coeruleoalba*) IN THE CENTRAL TYRRHENIAN SEA (MEDITERRANEAN SEA) IN RELATION TO COMMERCIAL SHIPS

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INTRODUCTION This research was carried out during the "Cetaceans Sightings Cruise in the Central Tyrrhenian Sea" between October 1989 and September 1992. By direct observation, the behaviour of striped dolphins (*Stenella coeruleoalba*) was studied in connection with the presence of ferries.

METHODS Observations were made aboard ferries in the area of the Central Tyrrhenian Sea between the continental and Sardinian coasts. During three years research, it was possible to carry out 247 trips (one per week), in any sea condition, corresponding to about 2,000 hours of observations during which we recorded 452 sightings of striped dolphins. The observation height was 13 metres above sea level; the average speed of ships was 16-17 knots.

RESULTS On 77% of encounters, striped dolphins approached the boat (Fig. 1), but rarely seemed to be disturbed by its presence as it moves away. On the majority of occasions, the animals performed "full leaps", while "half leaps", "vertical leaps", and "leaping and rolling" were observed with about the same frequency but less often (Fig. 2). Figure 3 shows the relationship between leaps and the sea state: As sea state increased, the frequency of leaps decreased. When sea state was equal to or higher than 3, the only leap recorded was "full leap". When the dolphins were indifferent to or went away from the ship, fewer leaps were recorded than when the animals approached the ship.

DISCUSSION AND CONCLUSIONS Although the reason remains unknown, it is clear that this species is very attracted to ships: we therefore consider that the transect line sampling method would probably lead to an over-estimation of numbers. During foraging and long distance movement, striped dolphins were indifferent to the presence of the ship.

The high frequency of the so-called "full leaps" may relate to an energetic saving, characteristic of the behaviour of striped dolphins. The meaning of the variety of leaps on the waves, prompted by the ship's presence, is still poorly understood, and at present, we simply classify them as "play activities" since their aim is not directed at feeding, emigration or any other immediate need. Perhaps this kind of leap relates to social interaction which in the striped dolphin is very complicated.

ACKNOWLEDGEMENTS We are very grateful to all those people who took an active part in this research as observers; to the officers and crews of the ferry boats; to the staff of the National Railway Board; and to the Environmental Bureau of the Provincial Administration of Rome.

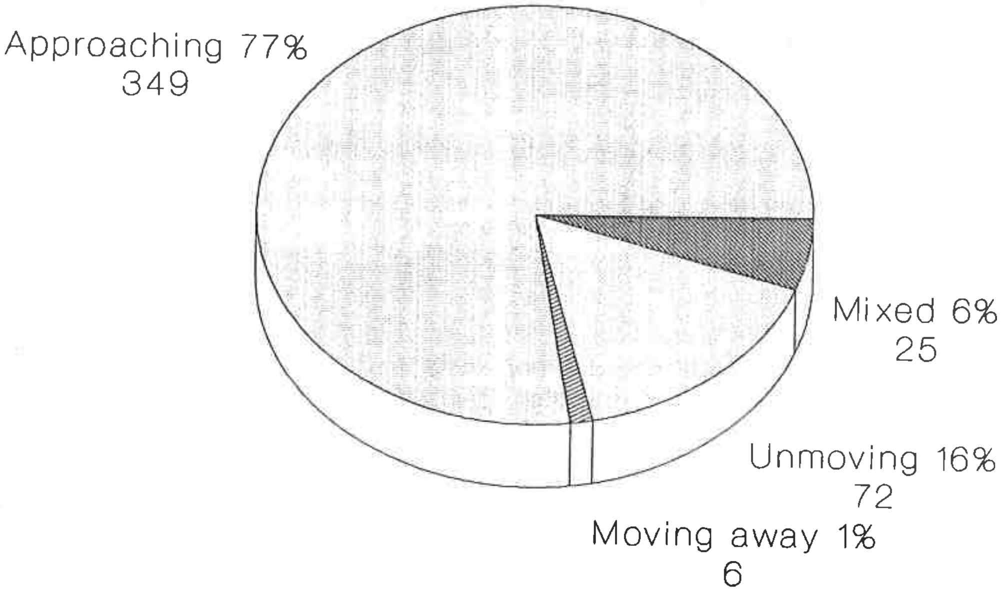


Fig. 1 Behaviour of striped dolphin towards ferries

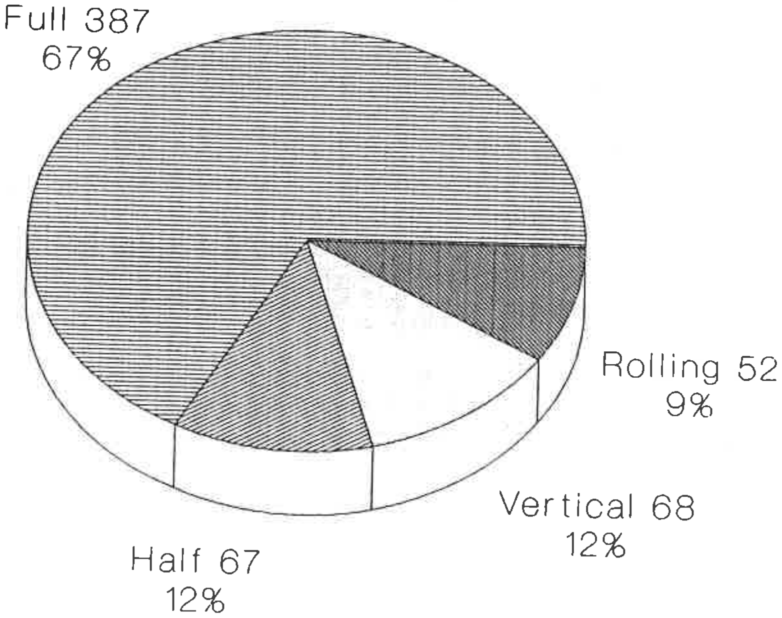


Fig. 2 Leaps of striped dolphin

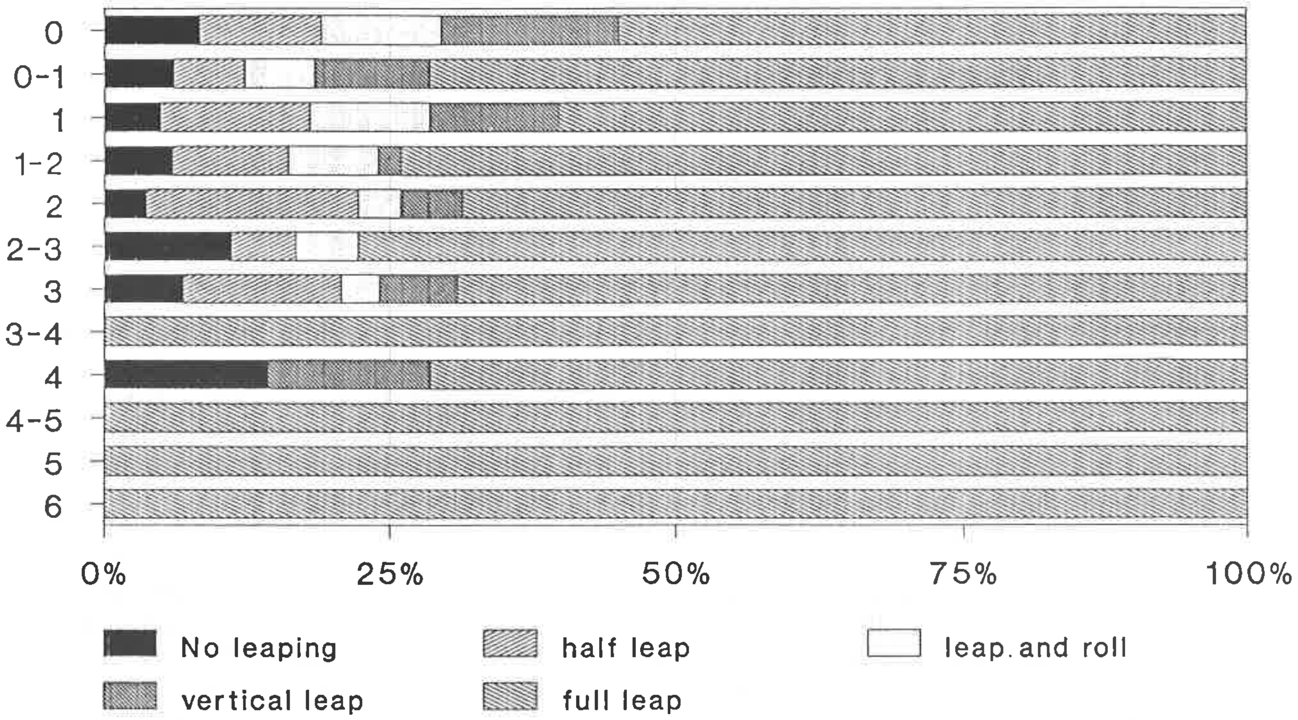
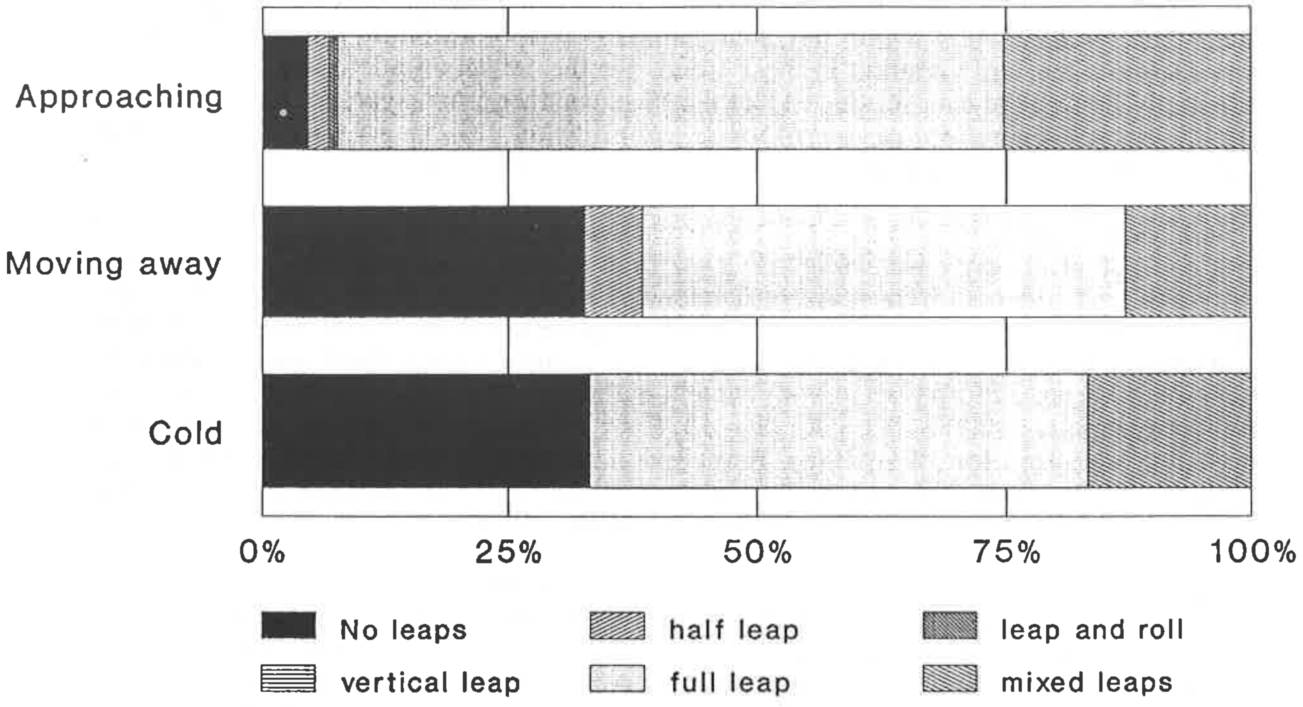


Fig. 3 Relation between sea state and leaping of striped dolphin



Mixed leaps are performed by large group

Fig. 4 Relations between leaping and behaviour toward the ferries

COMPARATIVE SOCIAL ECOLOGY OF DELPHINIDS

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INTRODUCTION The comparative approach has become a widely used tool in the attempts to understand the adaptive significance of species differences in morphology and behaviour within mammalian orders (Harvey and Pagel, 1991). However, many groups of mammals are under-represented in these comparative analyses because of the difficulties involved in collecting long-term observations. This is true for many nocturnal, arboreal or burrowing mammals, but also for the order *Cetacea*, the whales and dolphins.

The cetacean family *Delphinidae* is especially suitable for comparative examination. The delphinid cetaceans exhibit a wide variability in body size, brain size, sexual dimorphism and social dynamics, from the 40 kg Hector's dolphin to the 4000 kg killer whale. Because they live in such a different environment from that of terrestrial mammals, the study of delphinid cetaceans can provide a useful addition to an understanding of the ways in which habitat affects mammalian social systems. I will review morphological and behavioural information (specifically the relationships within and between body size, brain size, testes size, group size, diet and habitat preference) currently available for delphinids utilising a comparative approach and proposes hypotheses about their mating systems.

METHODS The comparative analysis of variation in morphological trends is best examined by establishing relationships at one taxonomic level and examining the deviance from these relationships at the taxonomic level immediately below this (Harvey and Pagel, 1991). Species are often not valid for comparison because of the lack of independence between species characters within the same genera. I will be examining trends within the family *Delphinidae* and variation in these trends for the 17 delphinid genera. This has not substantially limited the data set since 11 of the 17 genera are mono-specific. All data for the six multi-species genera (*Sousa*, *Lagenorhynchus*, *Stenella*, *Lissodelphis*, *Cephalorhynchus* and *Globicephala*) were calculated from means of the species values.

The data used in this review were collected from a wide variety of sources. Body size and length and age at maturity was collected from field studies when possible, but additional information was collected from reviews (Perrin and Reilly, 1984; Klinowska, 1991). Body weight was not available for eight species from six genera and the use of weight variables would have meant the loss of two genera (*Lissodelphis* and *Feresa*). There was a significant correlation between dimorphism in body weight and dimorphism in body length (Spearman Rank Correlation $r_S = 0.888$, $t = 6.96$, $df = 13$, $P << .001$), therefore sexual dimorphism in body length was used for all analyses. Brain size data were derived entirely from reviews (Ridgway and Bronson, 1984; Morgane and Jacobs, 1972). Testes weights were extracted from field reports and general reviews (Perrin and Reilly, 1984).

Body size has been shown to have a confounding effect on the comparison of morphological characters due to allometric growth (Harvey and Pagel, 1991). However, residuals from the straight line relationship of log transformed characters regressed on log body size will accurately describe character variation with the effects of body size removed. For this study, all measurements (body size, brain size and testes size) were log-transformed and the line of best fit was calculated by reduced major axis analysis.

Social and ecological categories of delphinids were assigned from general descriptions of distribution, behaviour and diet. Ecological parameters were classified as diet and habitat. Diet was classified into three categories: 1) feeding on fish 2) feeding on squid, and 3) feeding on other marine mammals. Habitat zone was classified into four categories: 1) estuarine, or occasionally entering fresh water, 2) coastal, 3) shelf, or ranging from nearshore to the continental shelf, and 4) pelagic, or always offshore.

RESULTS There were twelve possible combinations of the three diet and four habitat categories, but only eight were observed. Fish feeders were found in all habitats, but there were no squid feeders which were predominately coastal or estuarine, simply because of the primary shelf and pelagic distribution of squid. The genera which hunted other marine mammals were found only along the continental shelf and in the pelagic zone.

Sexual Dimorphism Sexual dimorphism in body length in relation to mean body length of males and females for the 17 genera in the family *Delphinidae* is presented in Fig. 1. Sexual dimorphism was significantly correlated with average adult body length ($r_S = 0.51$, $t = 2.296$, $df = 15$, $P < .05$). The genus *Cephalorhynchus*, the smallest delphinids, was the only genera in which females were larger than males (mean body sizes of 1.39 m vs. 1.36 m; male: female length ratio = 0.978). Males were larger than females in all other genera. Although the degree of sexual dimorphism was significantly correlated with body size, the genera with the greatest sexual dimorphism, *Globicephala* (mean body sizes of 5.11 m for males vs. 4.12 m for females; male: female length ratio = 1.24), ranked only third largest in size. The medium-sized dolphins ranged between these two extremes.

Sexual dimorphism was compared for the ecological classifications of the genera. There were no significant differences which could be related to the eight ecological categories of diet and habitat (Kruskal-Wallis $H = 8.144$, $df = 7$, $P > 0.05$). Diet and habitat were also tested separately, but there were still no significant differences (diet: $H = 3.757$, $df = 2$, $P > 0.05$; habitat: $H = 5.378$, $df = 3$, $P > 0.05$).. There were also no significant correlations for sexual dimorphism and group size (minimum group size $r_S = 0.057$, $t = 0.221$, $df = 7$, $P > 0.05$; maximum group size $r_S = 0.064$, $t = 0.248$, $df = 7$, $P > 0.05$).

Relative Brain Size Brain weight was significantly correlated with body weights for eight genera of *Delphinidae* (Fig. 2: $r = 0.97$, $t = 9.59$, $df = 7$, $P << .001$. Reduced major axis analysis resulted in a linear equation for the natural log-transformed data: ln Brain Weight (g) = .51 ln Body Weight (kg) + 4.64. The slope of this line (0.51 ± 0.04) was equivalent to estimates made using all odontocete cetaceans (0.55 ± 0.17, principle components analysis, n = 24 species: Worthy and Hickie, 1986).

Residuals calculated from the reduced major axis were termed Relative Brain Sizes (RBS) and show the degree to which the different genera deviated from family-wide trends, independent of body size (Harvey and Pagel, 1991). *Tursiops* had the largest RBS, with a brain 21% larger than that predicted by the reduced major axis fit. *Grampus* and *Orcinus* also had brain sizes larger than expected (19% and 8%, respectively). *Globicephala* had the smallest RBS (36% less than expected), while *Delphinus* was also less than expected (8%). The other genera were all within 5% of the predicted values. None of this variability could be explained by the combined ecological classifications (Kruskal-Wallis $H = 4.0$, $df = 5$, $P >> 0.05$). Separate tests were run on diet alone and habitat alone, but there were no significant trends (diet: $H = 0.5$, $P >> 0.05$; habitat: $H = 3.1$, $P > 0.05$). There were no significant correlations for either of the group size estimates (minimum group size $r_S = -0.51$, $t = 1.46$, $df = 7$, $P > 0.05$; maximum group size $r_S = -0.57$, $t = 1.71$, $df = 7$, $P > 0.05$).

Relative Testes Size The combined weight of both testes was examined in relation to male body weight for 13 delphinid genera (Fig. 3). The relationship between testes weight and body weight was described by the reduced major axis line of best fit: ln Testes Weight (g) = 0.95 ln Body Weight (kg) + 2.79. This relationship was significant ($r = 0.86$, $t = 5.64$, $df = 12$, $P < 0.001$). Relative Testes Sizes (RTS) were calculated as observed/expected ratios from the line of best fit. There were no clear patterns in the taxonomic distribution of RTS values: members of all subfamilies had representatives with larger than expected testes size. There were also no significant correlations between testes size and group size (minimum group size r = 0.19, t = 0.20, df = 12, P >>0.05; maximum group size r = -0.01, t = 0.01, df = 12, P >>0.05).

DISCUSSION The comparative analysis of morphological and behavioural characters within the cetacean family Delphinidae was limited by available data. However, trends in the relationship between body size and the characters of sexual dimorphism, brain size and testes weight were not substantially different from those described for terrestrial mammals. On the other hand, there were no clear correlations between these characters and the behavioural and ecological features of group size and feeding preferences. Perhaps there were problems with the taxonomic classification of prey items when prey schooling behaviour or caloric value may be a better prey classification scheme.

Sexual dimorphism (with males larger than females) is considered to have evolved because bigger males are better equipped to compete with other males for access to females, and in turn, that females could choose to mate with larger males. The indications of the degree of male-male competition in delphinids is predominately anecdotal, based on limited observations or on the occurrence of body scarring. The species with the greatest dimorphism (*Orcinus* and *Globicephala*) appear to live in very cohesive societies with stable relationships. Male-male competition may only occur in highly ritualised interactions, as has been observed in all male groups of *Orcinus* in tight body contact (Heimlich-Boran & Heimlich-Boran, ms.) In summary, the evidence for male-male competition in delphinids is still unclear. However, the lack of observations of aggressive male:male interactions in *Orcinus* over 20 years of study, suggests it does not play a major role. The detailed patterns of delphinid mating systems must be explained in terms of reproductive success before the role of sexual dimorphism can be understood.

Analyses of Relative Brain Sizes (RBS) for nine genera of *Delphinidae* identified that variability in brain size was independent of body size. However, none of the social and ecological classifications identified any significant trends. Larger RBS's may provide the improved neural processing needed to locate patchy food resources. This diet hypothesis did not apply to delphinids; for example, the two squid-feeding species (*Globicephala* and *Grampus*) were found to have very different RBS's.

Another hypothesis to explain relatively larger brains in comparative studies has been the *social complexity* hypothesis, which suggests that large brains are needed to live in complex social groups. The only social variable for delphinids which was used to test this hypothesis was group size. No significant trends were found, but perhaps other elements of society (such as socionomic sex ratio) may explain the variability in brain size better. The two genera for which we possess the most information on social structure, *Tursiops* and *Orcinus*, both have relatively larger brains than other delphinids. This is consistent with a social complexity hypothesis. However, *Globicephala*, which appears to share many elements of complex social structure with *Orcinus*, had a relatively much smaller brain. It is likely that the large brain of delphinids is specialised for acoustic signal processing, especially echolocation. The use of broad band clicks, rapid click repetition rates (up to 1000/sec.) and the fine-grained resolution of delphinids likely requires a great deal of neural processing (Wood and Evans, 1980). This could explain the large relative brain sizes compared to other mammals (Worthy and Hickie, 1986).

Kenagy and Trombulak (1986) were the first to suggest that odontocete cetaceans have exceptionally large testes compared to other mammals. Observations from captive *Tursiops* suggest that mating occurs promiscuously. However, in this study, *Tursiops* had relatively small testes for a delphinid. This would appear to indicate that other delphinid species (previously unstudied) have even greater potential for sperm competition.

This study may require additional data before meaningful comparative relationships become apparent. However, it may also be that the different selective pressures of living in a three-dimensional, gravity-free environment has resulted in unique adaptations for the social delphinids.

REFERENCES

Harvey, P.H. and Pagel, M. 1991. *The Comparative Method in Evolutionary Biology.* Oxford University Press. 239 pp.

Kenagy, G.J. and Trombulak, S.C. 1986. Size and function of mammalian testes in relation to body size. J. Mammal. 67:1-22.

Klinowska, M. 1991. *Dolphins, Porpoises and Whales of the World: the IUCN Red Data Book.* Gland, Switzerland: IUCN. 429 pp.

Morgane, P.J. and Jacobs, M.S. 1972. Comparative anatomy of the cetacean nervous system. pp. 117-244 IN: R. J. Harrison (eds). *Functional Anatomy of Marine Mammals.* London: Academic Press.

Perrin, W.F. and Reilly, S.B. 1984. Reproductive parameters of dolphins and small whales of the family *Delphinidae.* Rep. Int. Whal. Commn. Special Issue 6:97-125.

Ridgway, S.H. and Brownson, R.H. 1984. Relative brain sizes and cortical surface areas in odontocetes. Acta Zool. Fennica 172:149-152.

Worthy, G.A.J. and Hickie, J.P. 1986. Relative brain size in marine mammals. Am. Nat. 128:445-459.

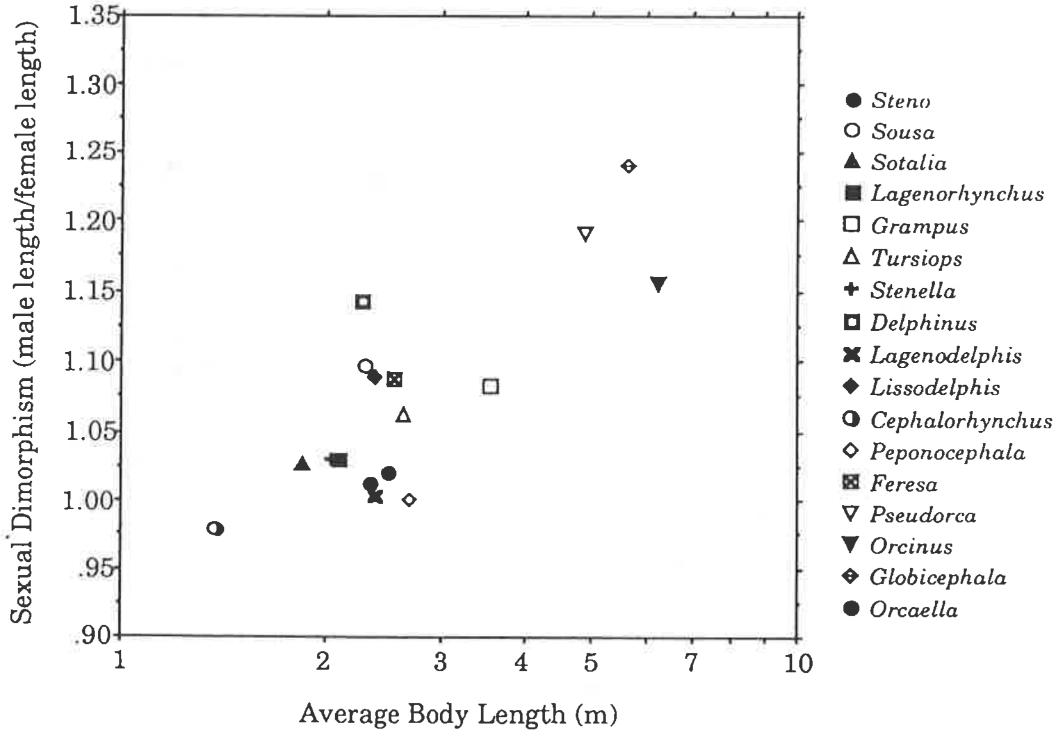

Fig. 1 Sexual dimorphism in body length plotted against average of adult male and adult female body length for 17 genera of Delphinidae. All data were calculated from generic averages of species values

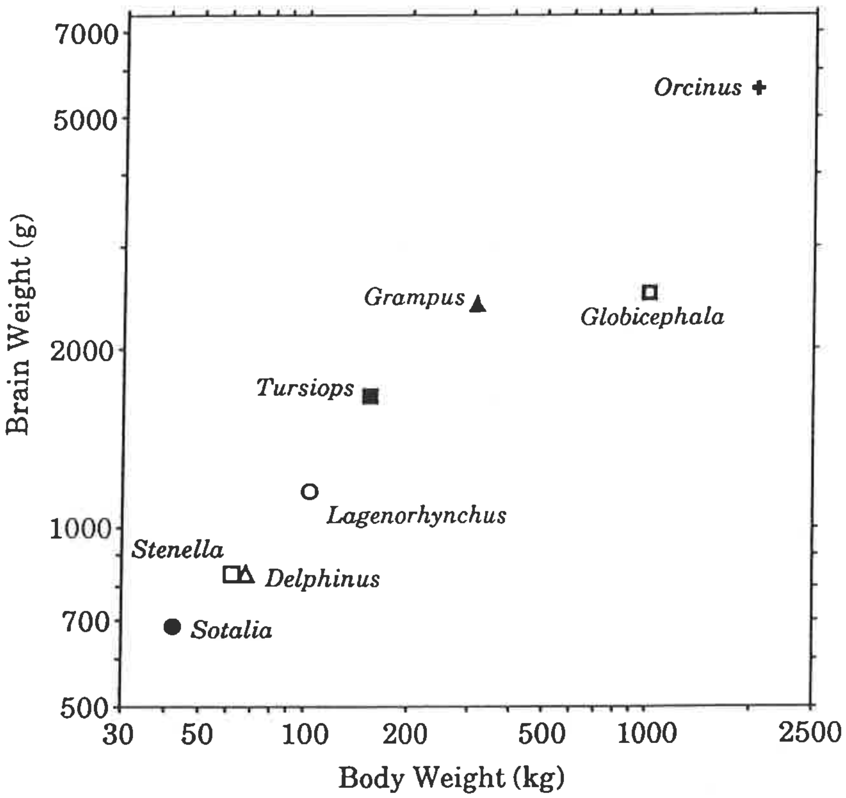

Fig. 2 Brain weight plotted against body weight for eight genera of *Delphinidae*. The data were significantly correlated (r=0.97, t=9.59, df=7, P<<.001).

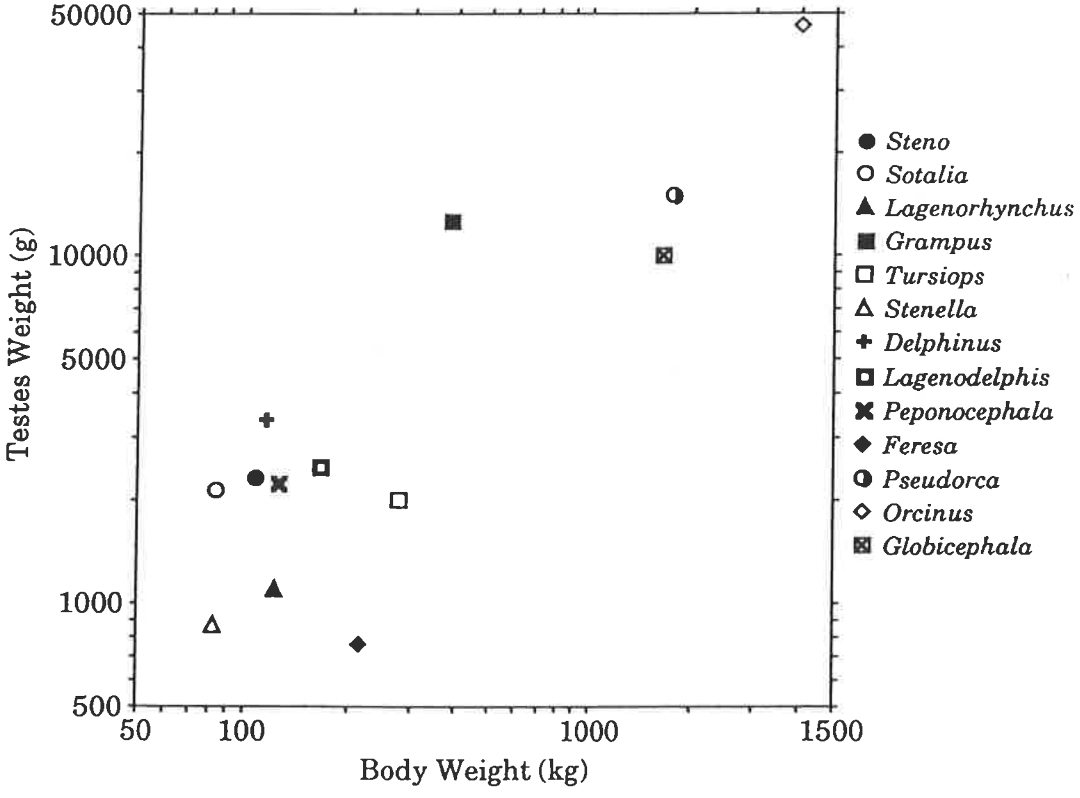

Fig. 3 Combined testes weight (g) plotted against body weight (kg) on a logarithmic scale for 13 genera of *Delphinidae*.

ACOUSTIC ASSESSMENT IN SPERM WHALES: A NEW EXPLANATION FOR SEXUAL DIMORPHISM IN HEAD SIZE

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Sperm whales are the most sexually dimorphic of cetaceans with mature males weighing some three times as much as mature females. Relative head size also differs between the sexes accounting for 26% of total length in mature males and only 20% in mature females. It is known that spacing ot the distinct sound pulses, typically found in sperm whale clicks, are related to head size. These pulses may be formed when a click is reflected between sound mirrors at either end of the whale's spermaceti organ. Inter-pulse intervals can therefore provide a measure of head size, and hence body length, in sperm whales. Male sperm whales are known to engage in fierce fights with other males which can result in serious injury.

Evolutionary theory predicts that in such potentially damaging contests, protagonists should attempt to assess each other's fighting ability before escalating conflicts. Size is likely to be a good predictor of fighting ability. (In fact this is probably the reason for the evolution of sexual dimorphism in body size in this species.) The visual assessment of size underwater is made difficult by limited visual range and the absence of good cues for range or size. It might be expected therefore, that sperm whales would attempt to assess size acoustically by attending to inter-pulse intervals in the clicks of rivals.

Comparisons with other species suggest that sperm whales should have the auditory ability to make this discrimination. If males started to assess size acoustically then any whale with a proportionally longer head would be assessed by his rivals as being larger than he really was. In this way he might prevail in contests by "bluffing". This would create selection pressure for increases in head size. Since fights are most common between males, the selection pressure for increased head size will be greater for males than females, and lead to the sexual dimorphism for porportional head size observed in this species.

DOLPHIN COMMUNICATION

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INTRODUCTION This study was self-initiated, self-financed and carried out by students of several disciplines. Due to the lack of studies on free-living dolphins, the aim of the students was to check the possibility to record the **sound repertoire and behaviour of odontocetes in the wild.** Emphasis was placed on the correlation of the dolphins' sounds with their behaviour, which required synchronous film and tape recordings. The results of this study with unusual equipment are remarkable:

Some typical sounds of common dolphins (*Delphinus delphis*) could be determined in relation to their behaviour

The hunting procedure could be specified

The thesis of the signature whistle could be thrown into doubt

Studies in dolphinaria where the number of vocalisations may decrease, tank reverberation may cause changes in temporal and amplitudinal aspects of vocalisaton, (Au *et al.*, 1985) and drastic environmental change (from wild to captivity), has a strong influence on the dolphins' behaviour and the sounds they emit, studies in the wild themselves pose many technical and logistic problems, but should at least provide results which represent realistic features.

EQUIPMENT The equipment used (Fig.1) consisted of a triangular platform which could be lowered to depths between 10 m and 60 m, on which was mounted a CCD-supervison camera (sponsored by Philips), coupled wth a hydrophone (100 Hz) (loaned from FWG), an UHER 4400 tape recorder and other electronic equipment (lamps, accumulators etc.).

Events underwater could continuously be observed on a monitor which was coupled to the CCD-camera and registered on a video recorder. Furthermore, additional video recordings were obtained by a diver with a portable underwater video camera.

The investigations were carried out in summer 1989, from July to October, in the bay of La Herradura, Southern Spain. With the help of the diving centre 'Club MARSUB' it was possible to carry out this 'student-low cost-project' on a large school of common dolphins some miles off the coast. One advantage was that this region could be characterised by an extremely low ambient noise level and little ship traffic.

RESULTS AND DISCUSSION

Analysis of sounds Since the methods of analysis and their representation have a geat influence on the description of sounds, two completely different kinds of analytical techniques were used: the 1/3-octave-flter-analysis and the Fast-Fourier-Transformation (FFT)-analysis.

FFT analysis Figures 2 and 3 show the frequency dependent power spectrum of the whistles of common dolphin within a mean duration of 1.1-1.4 sec, which was calculated with the help of 140-180 non-overlapping 512-FFTs, depending on the length of the sounds.

The sample frequency was 16.4 kHz; this corresponds - related to real time - to a sample frequency of 65.5 kHz, with a Nyquist frequency of 32.8 kHz. Since the frequency limitations of the recording equipment is about 25 kHz, an aliasing effect can be excluded.

Figure 2 shows a whistle, which we characterised as type Ia by the frequency modulation starting around 12-14 kHZ, descending to 7-8kHz and rising again to 10-12 kHz. The mean duration of all recorded sounds was 1,080 ms. Figure 3 shows a whistle of type Ib with a slightly longer duration of 1,200 ms and a frequency modulation of 15 kHz, descending to 7.4 kHz rising to 11.4 kHz and descending again to 7 kHz.

Lateral effects The permanent tone at a frequency of 17 Hz occurs during the display by the tape recorder. The second energy maximum occurring 50ms after the main energy maximum cannot be explained by a copy-effect, occurring by the superimposition of the magnetic field lines to the tape wire. The possibility that there is a reflection off the bottom, the sea surface or a fish school could not definitely be determined. The figures show harmonics (representing the second harmonics) which are very probably made during sound production.

The next most frequent sounds were those referred to as type Ia and Ib. Other sounds were only heard once or twice during the recording period.

1/3-Octave-Filter-Analsis The results of the 1/3-Octave-Filter-Analysis will be discussed by using the example of a type I sound. Figures 4 to 6 show the energy distribution of the 1/3-octaves at different moments during sound production illustrated in Figure 2. It can be seen that the mean energy occurs in the central frequencies of 8.0 kHz, 10 kHz and 12.4 kHz.

The sound begins within a range of 11.2 to 14.0 kHz (Fig. 4), then descends to a range of 7.1 to 9.0 kHz (Fig. 5), and finally rises again to a range of 9.0 to 11.2 kHz (Fig. 6). It is appreciable that the duration of descent from the 12.6 kHz 1/3-octave to the 8.0 kHz 1/3 octave is nearly the same as the duration of the following rise. Moreover, it can be seen that the dolphin is capable of shifting the total amount of sound energy from one 1/3-octave to the other in a few milliseconds. A difference in sound energy from a 1/3-octave to another of 12 dB corresponds to an enhancement of 400%.

Correlation We had the opportunity to record a group of dolphins during their feeding period. Fortunately, we were able to relate at least some of the recorded whistles of types Ia and Ib to the vocalising dolphin. When approaching the diver, a dolphin often emitted trains of long and loud whistles whch corresponded to the production of streams of bubbles from its blowhole. It is known that bubbles can also be produced without acoustic emissions, but in our study, the correlation was very clear: the emission of the streams of bubbles continued for the same length of time as the emission of the whistles, which had a duration of up to 1.4 sec. In this way, about ten whistles could be related to one dolphin. The animal emitted whistles of types Ia and Ib (see Figs. 2 and 3) and, less frequently, whistles with an almost constant frequency of another type (not represented here). These results call into question the thesis of a signature whistle, because the dolphin emitted at least two different whistles.

Behaviour during feeding Common dolphins are known to hunt in the late afternoon and early evening (Barnes and Creagh, 1988). The common dolphins observed during feeding had a group size of 30-40 animal (adults, subadults, females and calves). During the long process of feeding, it appears that the dolphins actively herd the fish (subadult *Belone belone)* towards the surface, using it as a barrier through which the prey cannot escape. Our observations suggested that dolphins swimming underneath the school prevented the fish from escaping downward, whereas those maintaining a short distance from the school rather close to the surface were obviously preventing a lateral escape route.

The actual process of feeding, i.e. the attacks on the school, proceeded as follows: two or more dolphins swimming underneath the school (at depths of 5 - 10m) suddenly came up at a sharp angle, "shooting" into the packed school. During the attack and even sometimes shortly beforehand, the dolphins swam synchronously. Immediately after the attack, they returned almost to the same spot, where they swallowed their prey.

The precise location of the attack could also be recognised from the boat by small numbers of fish jumping out of the water, followed by the attacking dolphin. Sometimes the dolphins even emerged completely from the water. Females with calves were not observed feeding, but they may easily have done so before our arrival or even during out study, because it was impossible to monitor all the animals simultaneously.

Sounds during hunting Most whistles of type Ia and Ib were heard during feeding. The question is whether these whistles characterise a single dolphin, the entire school, or a portion of the feeding process.

We could not definitely say that these sounds are characteristic for dolphin schools because the animals were only observed during the feeding period. The thesis that the type of sounds depends on the situation seems the most probable one. Since it was quite easy to observe, there appears to be good co-ordination between the animals of a single group. On the one hand, this was noticeable in the division of labour between the hunting dolphins and the ones which herd the fish school into one place; on the other hand, it was reflected in the frequent attacks of the prey swarm by two or three animals.

CONCLUSIONS By combining optical and acoustic recordings obtained during this project, it was possible to show some behavioural characteristics such as the partitioning of work during feeding activity and the hunting procedure. Moreover, we were able to prove that common dolphins mainly emit sounds of one type during their main feeding activity. But it could also be shown that an individual within the school is able to emit at least two different types of sounds.

For detailed characteristic data of a sound, the FFT-analysis is more useful than the 1/2-Octave-Filter-Analysis; but for longer sound trains, the latter is more practical.

ACKNOWLEDGEMENTS Since our project was initiated on a private basis it would have been impossible to carry it through without the help of industry or institutes. We would like to thank Philips Germany for lending us the excellent CCD-monitor camera with the equivalent monitor and placing at our disposal a digital oscilloscope. Grundig helped us with their newest SVHS video camcorder incorporated in the underwater case. We thank Dr. P. Diekmann and Dr. U. Petersohn from the Institute of Applied Physics, University Kiel, for their encouragement as well as for the electrical equipment they gave us.

Finally, our project would never have been realised without the help of Christian's father Michael Haag, who besides offering us the facility to contact several industrial enterprises and supporting the whole project financially, also showed high personal engagement and commitment during the main phase in Spain.

REFERENCES

Au, W.W.L., Cardane, D.A., Penner, R.H., and Scronce, B.L. 1985. Demonstration of adaption in beluga whale echolocation signals. J. Acoust. Soc. Am. 77(2):726-730.

Barnes, L.G. and Creagh, C. 1988. Kinds of whales. In *Whales, Dolphins and Porpoises.* (Eds. R. Harrison and M.M. Bryden). Merehurst, London.

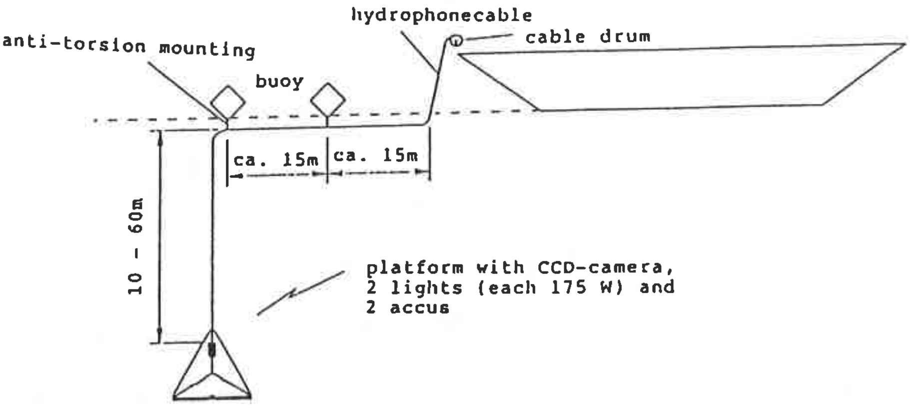

Fig. 1 Sound and video recording arrangement

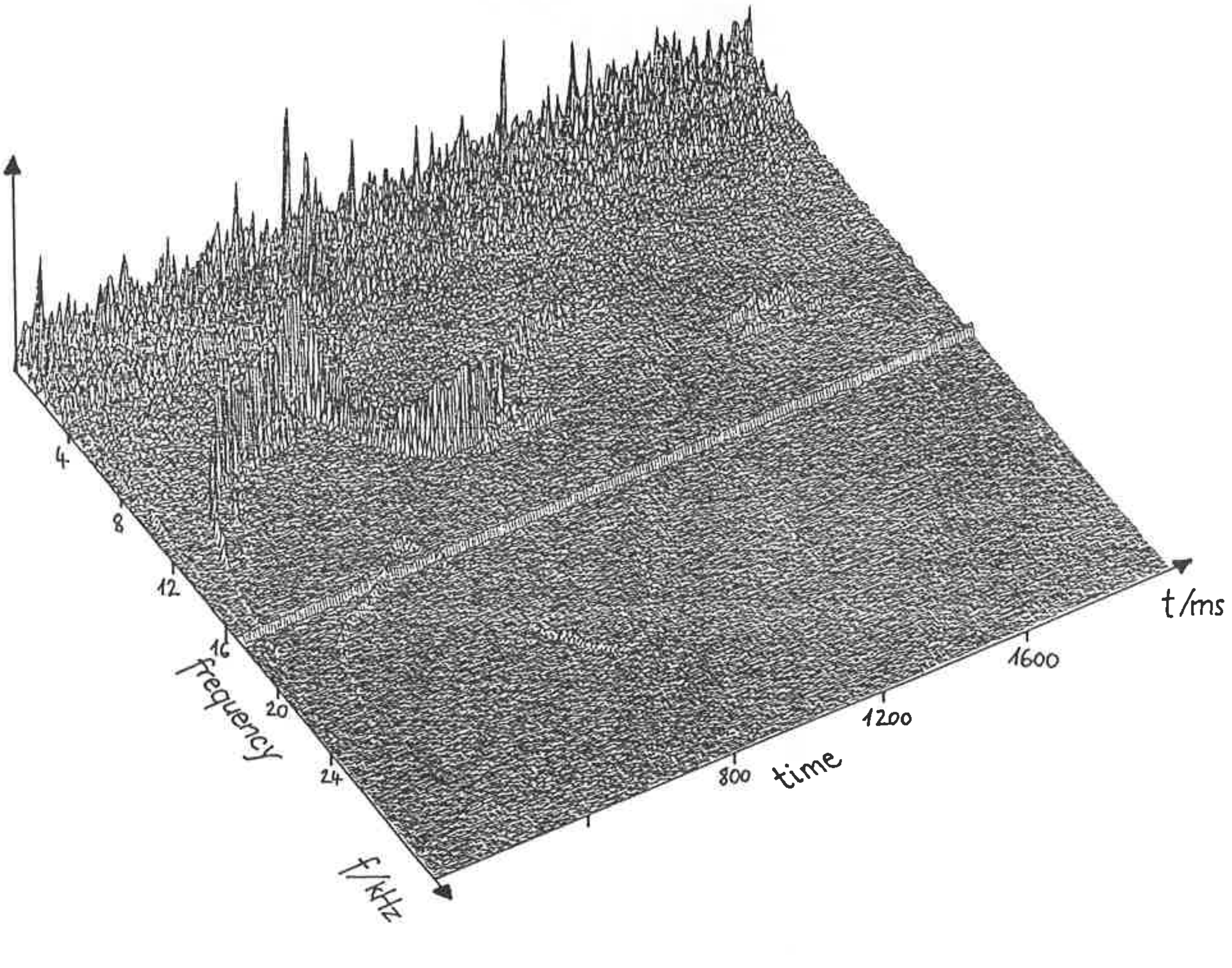

Fig. 2 An FFT-meshplot of sound type Ia

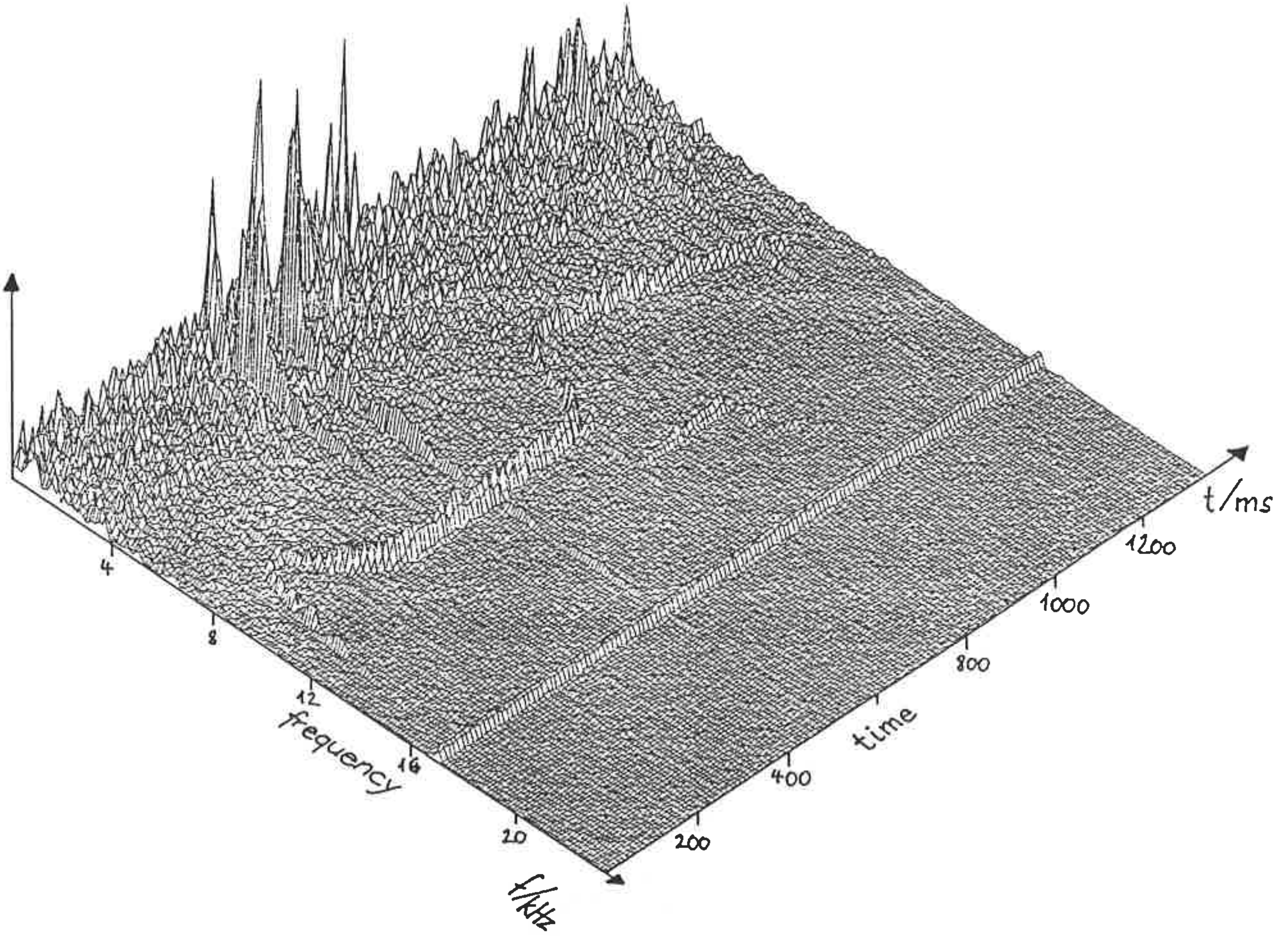

Fig. 3 An FFT-meshplot of sound type Ib

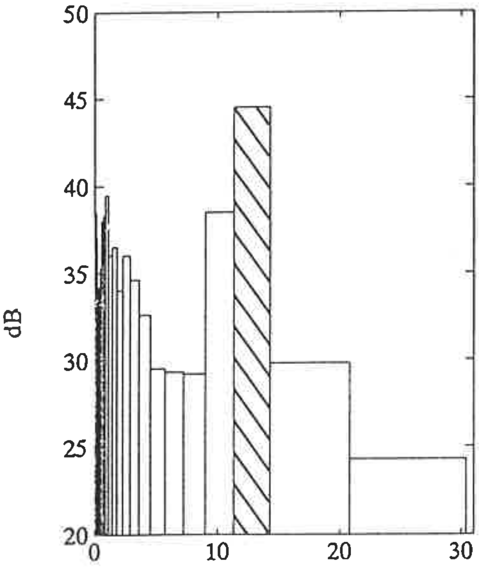

Fig. 4 (at 300ms)

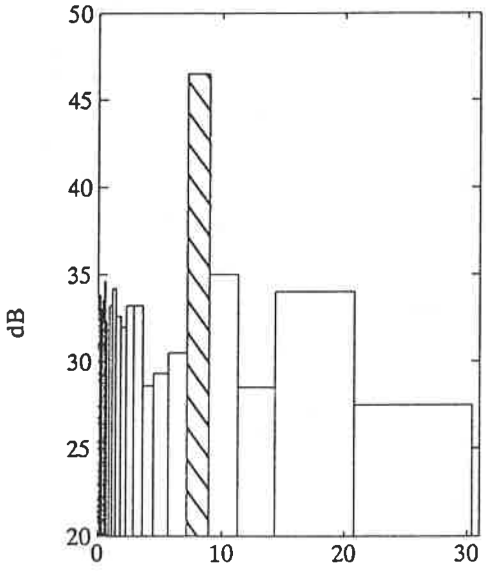

Fig. 5 (at 400ms)

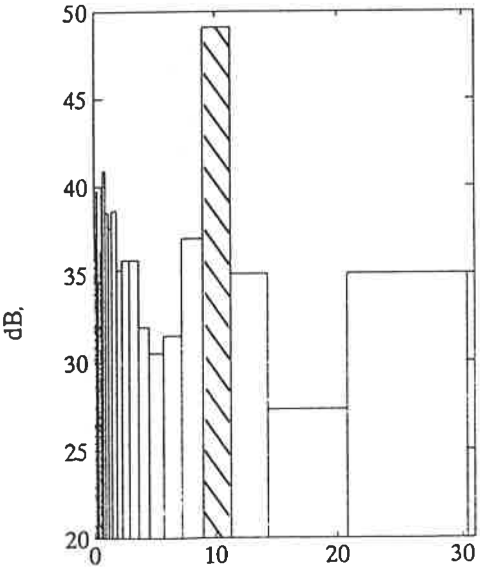

Fig. 6 (at 700ms)

1/3-octave-filter-analysis of sound type Ia

SEASONAL DISTRIBUTION AND FEEDING ECOLOGY OF KILLER WHALES IN NORTHERN NORWAY

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INTRODUCTION Since 1983, killer whales (*Orcinus orca*) have been photo-identified around the islands of Lofoten and Vesterålen in northern Norway. To date, 380 individuals and 44 groups have been identified. Earlier studies have shown that the seasonal distribution of killer whales along the coast of Norway is closely related to the distribution of herring *(Clupea harengus)* (Christensen, 1988). In the study area, killer whales are most abundant in October-January when herring overwinters in the fjords, but little is known about distribution and abundance during summer (Christensen, 1988). The analysis of stomach contents have shown that herring is the main type of prey during autumn-winter, but nothing is known about the types of prey during the summer (Christensen, 1982). The aim of this study was to learn more about the seasonal distribution and choice of prey of killer whales in the study area. During autumn, the habitat use and the way that killer whales catch herring have been studied.

MATERIALS AND METHODS Fieldwork was carried out in 1990-1992 during January-February, June-August, October-November. The whales were searched for using various boats ranging from 20 to 100ft in size. During each encounter, the whales were photo-identified.

Prey species were identified during encounters with feeding whales, either from direct observations of the prey species (prey species identified at the surface or with underwater camera), or with an echosounder combined with information received from fishing boats operating in the area. Information on the distribution of herring and mackerel (*Scomber scombrus*) was received from the Institute of Marine Research, Bergen.

Feeding behaviour was observed in October-November both from the surface and underwater using video cameras. Habitat use was studied during October-November in combination with the photo-identification and feeding behaviour studies. The behaviour of the whales was observed at 15-minute intervals and the positions were marked on a map of the study area divided into 1nm^2 to determine whether certain areas were preferred for feeding.

RESULTS Killer whales were encountered on 304 occasions during 1992-92. In 1992, around 90% of the groups encountered were re-sightings from previous years. The distribution pattern of the whales was different between summer and autumn-winter. The whales were most abundant during October-November when an estimated 500 whales followed herring into Tysfjord-Ofotfjord (Fig. 1) (Similä and Christensen, 1992). These fjords have been the main overwintering area for the spring-spawning stock of herring since 1987 (Anon, 1990). In summer, killer whales were less numerous (on average, 5-6 different groups encountered) and seen mainly in offshore waters outside the islands of Lofoten and Vesterålen (Fig. 1). The concentration of sightings around Andenes (Fig. 1) is caused by whale-watching trips that operate on a daily basis during summer. The summer distribution area correlates well with the area where herring can be found during this period (Anon, 1990, 1991, 1992). In summer 1991, mackerel was also present in the summer distribution area of killer whales. Five of the groups have been encountered only in summer, 21 groups only in autumn-winter, 17 groups during both seasons, and one group only in late winter.

Prey species have been identified on 56 occasions during autumn-winter, and on nine occasions during summer. In autumn-winter, the prey was identified as herring on 54 of those occasions; the whales also fed on single occasions upon eider ducks (*Somateria mollissima*), and little auks (*Alle alle*). During summer, killer whales have been recorded feeding on herring during eight of the observations, and once on a northern fulmar (*Fulmarus glacialis*).

Feeding behaviour was observed on 92 occasions, for 83 hours from the surface and for five hours underwater. Killer whales used three different co-operative techniques to hunt herring: (1) the whales chased herring into small bays; (2) the whales chased and fed on herring at more than fifteen metres depth; and (3) the whales chased herring in a tight concentration close to the surface, stunned the fish by tailslaps and ate them one by one (Ugarte and Similä, this vol.). None of these methods involved the whales feeding on the vast mass of herring found at 150-250m depth during daytime, instead concentrating on smaller patches found closer to the surface.

The areas where feeding observed were compared to the depths given on a chart of the study area; 99% of the feeding occurred in areas less than 200m in depth. Twenty-one observations (23%) were made in an area with high underwater seamounts.

DISCUSSION The same whales were re-sighted in the study area each year which indicates that there is a regularity in the seasonal movements of killer whales in the area. The areas of distribution were different between autumn-winter and summer, which probably can be explained by differences in the distribution of preferred prey. Killer whales were most abundant in the study area in October-January when herring overwintered in the fjords. Herring was the main type of prey during this time. There were only a few direct observations of feeding whales in summer; however, the results indicate that herring might be an important part of the diet also during the summer.

Herring, mackerel, squid, and marine mammals are possible main prey items of killer whales in the study area, according to information on their diet in Norway and other parts of the North Atlantic (Sigurjonsson and Leatherwood, 1988). Herring is known to be a major part of that diet. Mackerel was found in the same area as killer whales during summer 1991 (Anon, 1992) but it is not known if the whales consumed this species. There is no information on squid from the area and therefore it is not possible to draw conclusions on the role they might play in the diet of killer whales. During the three years of fieldwork, no encounters with killer whales preying on marine mammals were made and it can be concluded that marine mammals are at least not an important part of their diet in the area.

Eider ducks, northern fulmars and little auks have not previously been reported being eaten by Norwegian killer whales. All of these birds have been observed being consumed only once and are thus probably not an important part of the diet.

The best method for identifying prey species was observations made during encounters with feeding whales. This method has obvious limitations when the whales are feeding deep (>15m), and in these situations, the use of sonar combined with trawling might prove useful.

The reason why killer whales were feeding on smaller patches of herring and not the vast majority of overwintering herring could be that these patches are found closer to the surface and are easier to "control". The fact that whales preferred shallower areas for feeding could be explained either by the fact that the patches of herring were more common in these areas or that the fish were unable to escape to deep waters in shallower areas.

There were differences in the seasonal distribution of the groups and it is possible that they represent differences in prey choice. However, the division into groups seen only in autumn-winter and groups seen both in autumn-winter and summer might be artificial since the summer distribution area was not covered as effectively as the autumn-winter distribution area. During each summer, new groups were seen in both seasons, and it might be that the majority of killer whales in the study area are present there, both during autumn-winter and summer. The NK-pod has been encountered every summer but never during autumn-winter when herring is abundant. Since the NK-pod has never been seen feeding, it is not possible to say if their diet differs from that of other whales. The NN-pod has been encountered in the study area only in late winter when the majority of herring and all the other killer whale groups have left the study area. The reason for this behaviour remains unclear.

This project shows that it is possible to study the seasonal distribution and abundance of killer whales by using the photo-identification method, and that prey species can be identified during direct encounters with feeding whales. To learn more about the distribution patterns, prey choice and possible differences between the groups, satellite transmitters should be used for following the the seasonal movements of the different groups and a combined sonar - fish trawling system should be used to identify prey species, particularly when whales are feeding at greater depth.

ACKNOWLEDGEMENTS Numerous people have helped us during this study. We want to thank especially Bo Johanneson, Ivar Christensen, Karin Karlsson, Rudolf Jakobsen, Russell Leaper, Jenny Burdon, Anders Svensson and Stefan Ostrowski. The study has been financed by the Academy of Finland, The World Wide Fund for Nature Sweden, the Norwegian Council for Fisheries Research and The Whale Centre in Andenes.

REFERENCES

Anon, 1990, 1991, 1992. Havforskningsinstitutt, Intern tokrapport Report of the Institute of Marine Research, Bergen Nordnes.

Christensen, I., 1982. Killer whales in Norwegian coastal waters. Rep. Int. Whal. Comm, 32: 633-672.

Christensen, I., 1982. Distribution, movements and abundance of killer whales (*Orcinus orca*) in Norwegian coastal waters, 1982-87, based on questionnaire surveys. Rit. Fiskideildar, 11: 79-88.

Similä, T. and Christensen, I., 1992. Seasonal distribution and abundance of killer whales around Loften and Vesterålen islands, northern Norway. ICES.C.M.1992/N:11.

Sigurjonsson, J. and Leatherwood, S. (eds), 1988. North Atlantic killer whales. Rit Fiskideildar, Vol. XI.

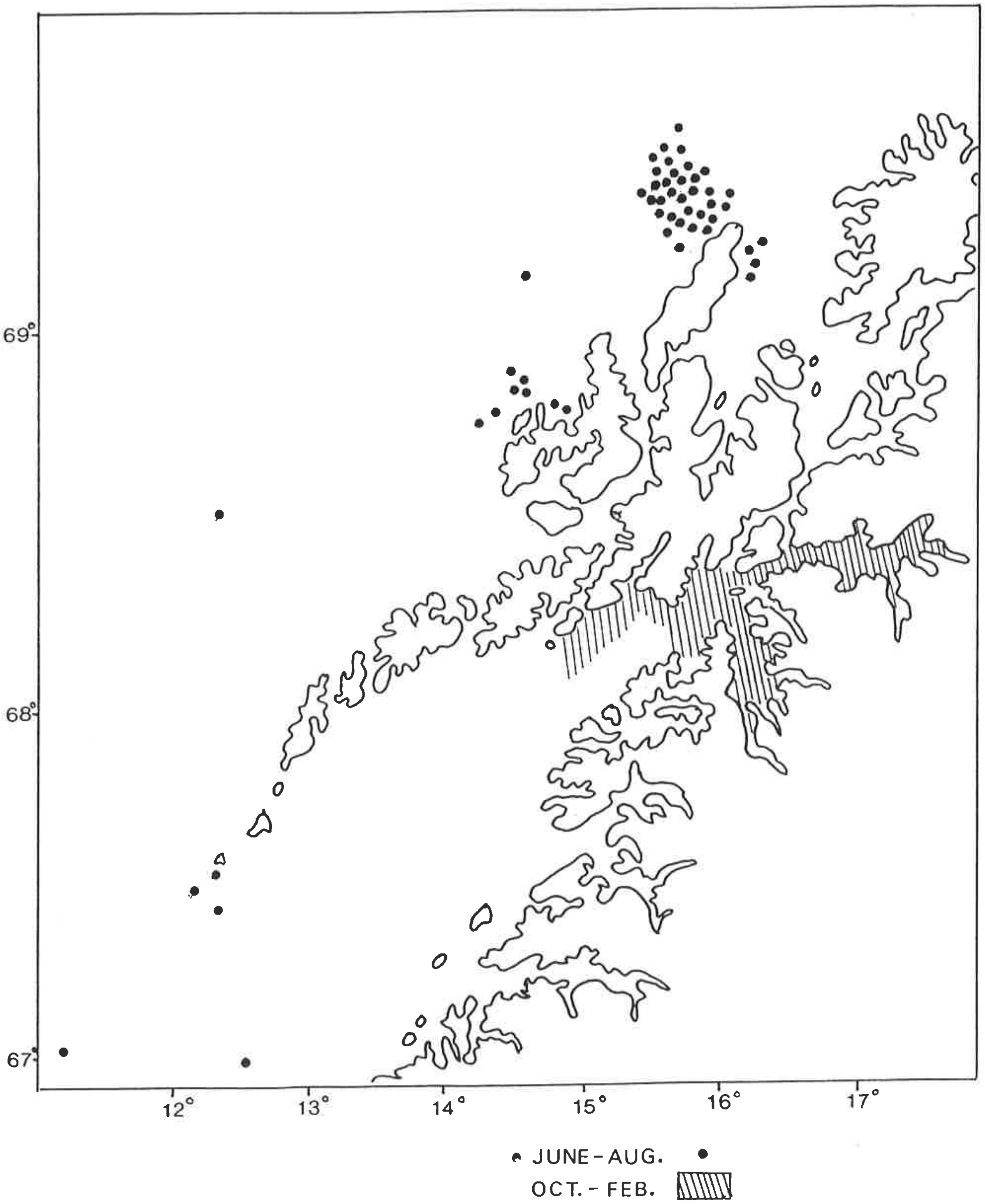

Fig. 1 Killer whale sightings, 1990-92

REPRODUCTIVE PARAMETERS OF FEMALE LONG-FINNED PILOT WHALES (*Globicephala melas*) AROUND THE FAROE ISLANDS

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Between July 1986 and June 1988, 3,250 long-finned pilot whales taken in the long-established Faroese drive fishery were carefully examined, measured and sampled as part of a multi-disciplinary research project. Using data from 1,680 females, estimates were derived for all the major reproductive parameters.

Females of this species ovulate for the first time at an average age of just over 8 years and continue throughout life, though at a decreasing rate. Conceptions are spread throughout the year, but peak in early July. There is evidence of high foetal mortality during the first six months of pregnancy, at least. Using novel analytical techniques, we estimate the gestation period in long-finned pilot whales to be around six months, some 3-4 months less than had been generally accepted. We will explain why most studies have over-estimated the length of pregnancy in cetaceans with a protracted breeding season, and the impact this has on estimates of other measures such as the duration of lactation and the rate of reproduction. It seems that pilot whales in this population have an average inter-birth interval of some 5 years, exceeded only by the killer whale (*Orcinus orca*) on current knowledge. Implications for the sustainability of the Faroese hunt are discussed.

OVARIAN ASYMMETRY AND FOLLICULAR DEVELOPMENT IN HARBOUR PORPOISE (*Phocoena phocoena* : Cetacea).

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In mammals, it is generally assumed that the reproductive organs are bilaterally symmetrical even in monotocous species. Nevertheless, anatomical and functional expressions of ovarian asymmetry have now been well documented in several mammalian species, including the small odontocete, the harbour porpoise (*Phocoena phocoena*). The aim of the present study was to (1) describe the growth and development of the ovaries; (2) analyse the follicular development; and (3) compare intra-ovarian vascular supply. The reproductive organs of 90 female porpoises, stranded or incidentally caught in commercial fishing operations, were collected from all Danish waters during January to December (1986-91). Growth of the left and right ovary was compared by weight in immature and mature animals. No significant differences were found between right and left ovary in the immature animal, mean weight 0.6g (SE 0.10, N = 55). At onset of sexual maturity (3 years of age) rapid growth was observed for both ovaries. The left ovary (mean 6.6g, SE 0.10, N = 55) was significantly ($p<0.05$) larger than the right ovary (mean 2.3g, SE 0.45, N = 35).

Although primordial follicles were present in both ovaries, Graafian follicles, CL and CA were noted only in the left ovary. Reproduction in porpoises is highly seasonal (Sørensen and Kinze, 1992), with a marked annual variation in follicle growth. In the left ovary, Graafian follicles are only found in July (max. diam. 14 mm), whereas follicular development beyond stage 7 (antral follicles, max. diam. 5 mm) was generally retarded in the right ovary. In pregnant animals the conceptions were always in the left oviduct or uterine horn. No apparent differences were found in the intra-ovarian vascular supply.

REFERENCE

Sørensen, T.B. and Kinze, C.C. (in press). Ophelia.

PRELIMINARY DESCRIPTION OF DIFFERENT STAGES IN THE REPRODUCTION OF THE MEDITERRANEAN STRIPED DOLPHIN

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Although several studies have been carried out at a macroscopical level in reproductive tissues or organs of striped dolphins (*Stenella coeruleoalba*), relatively little work has been carried out on histological changes. The scarce documentation of the histology of ovarian corpora and the uterus in odontocetes makes interpretation of these structures difficult in females. In males, histology is necessary to differentiate between immature, adolescent and resting mature animals.

This paper presents a preliminary study of the histological changes that take place in the ovaries, uterus and testes of the striped dolphin, with age and reproductive activity. The females analysed fall into the following categories: immature, anoestrous, pregnant, and post-reproductive. The males are divided into immature and mature.

MATERIALS AND METHODS The gonads and associated tissues were collected from dolphins stranded on the Mediterranean coast during the 1990 morbillivirus outbreak, and stored in 10% formalin for preservation. Haematoxylin-Eosine stained slides were prepared using standard techniques.

Age was determined by counting annual growth layer groups in haematoxylin-stained and decalcified sections of the tooth dentine.

RESULTS The testes of a two-year old immature male and a 15-year old mature animal were compared histologically. In the immature animal, the epithelium was bordered only by sertoly cells and spermatogonia and the seminiferous tubules presented a narrow lumen and abundant interstitial tissue. In the mature animal, the diameter of the seminiferous tubules was greater and the epithelium contained all stages of the spermatogenetic series; proportionally, the amount of interstitial tissue was lower. The presence of spermatozoa in the lumen indicated that the animal was in full spermatogenetic activity.

The immature female was two years old. The ovaries presented no signs of ovulation when examined macroscopically. The ovarian cortex showed several stages of follicular development including primordial follicles composed of a primary oocyte surrounded by a single layer of follicular cells and primary follicles with an enlarged oocyte surrounded by the zona pelicida, and more than one layer of follicular cells. The uterus presented a relatively thin endometrium with the stratum compactum appearing smooth at the surface and the stratum spongiosum presenting a poor glandular development and undeveloped blood suppply.

The anoestrous female was 17 years old. Macroscopically, the ovaries presented no signs of ovulation with no active or regressing corpus luteum. The left ovary had four corpora albicantia while the right one had none, indicating that ovulation had occurred in at least one of the ovaries. No milk was observed in the mammary glands. The cortex of the ovaries had follicles at different stages of development. In the uterus, the surface of the stratum compactum appeared smooth, and improved blood supply with more developed glands were observed when compared to immature females.

The pregnant female was 16 years old. Macroscopically, the right ovary contained an active corpus luteum and two corpora albicantia. The left ovary had no corpora. During necropsy, a foetus was found in the uterus. The uterus showed extreme proliferation and hypertrophy of the endometrial surface. The tubular glands proliferated to form numerous and convoluted glands of large diameter. The endometrium and myometrium reached their maximum thickness during pregnancy when compared to the other categories.

The sample also included a post-reproductive female. Macroscopically, the ovaries showed ten corpora albicantia (six on the left and four on the right). The dentinal counts indicated that this animal was 25 years old. Microscopically, there was no evidence of follicular activity. The ovarian cortex showed a total lack of follicles with much of the tissue appearing fibrotic. The uterine mucosa also appeared fibrotic and, although blood supply was observed, the uterine glands appeared disintegrated.

One of the females examined had four cystic corpora in the left ovary. No stigma was present in the surface. Microscopically, the cysts were composed of luteal cells undergoing fatty degeneration. A fibrous tissue was present between these cells and the cystic cavity.

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THE STOMACH CONTENT OF SOME COMMON DOLPHINS (*Delphinus delphis* L.) FROM THE LIGURIAN SEA

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INTRODUCTION Since the common dolphin (*Delphinus delphis* L.) is a cosmopolitan species, notes about its feeding habits are available from various sources (Norris and Prescott, 1961; Fitch and Brownell, 1968; Watson, 1985). Such studies, so far as we know, have not included the Western Mediterranean, where, however, competition with striped dolphin (*Stenella coeruleoalba* Meyen) is suggested by the inverse relationship in abundance of the two species (Viale, 1985). At the beginning of this century, common dolphins appear to have been common in the Gulf of Genoa (Poggi, 1986), while in the 1970's it was only occasionally found. There have been no more records of common dolphins in the area in the last ten years, while striped dolphins remain common.

The specimens of common dolphin whose stomach content are analysed here were killed for the preparation of "musciame", a preserved food item consisting of salted and dried fillets of meat. In the context of fishing for dolphins (which ceased in 1980 with the introduction of a Mammal Protection Act), during the 1977 and 1978 seasons, several stomach contents of small cetaceans were collected at Camogli, by M.R. Costa and M.Pessina, whose work is gratefully acknowledged. Only three common dolphins were to be found among these, a fact which probably reflected the progressive decline of this species. In order to make a comparison of feeding habits, two stomach contents of striped dolphins of the same origin and another more recent one derived from a specimen killed in a swordfish drift net, were analysed. All the dolphins were healthy animals of the same approximate size (90-100 kg), killed in the same season (July and August) in the Portofino area (Eastern Ligurian Riviera).

MATERIALS AND METHODS Three common dolphin specimens (male 215 cm, c. 100 kg; male 210 cm, 100 kg; female 200 cm, 90 kg) and three striped dolphins (female 90 kg; male 95 kg; male 206 cm) were dissected a short time after death and the gastric content was preserved by formalin fixation. Prey was identified at a taxonomic level in as detailed a manner possible, with the aid of collections of surface and mesopelagic organisms from the same area. Prey of common dolphins were counted and the biomass measured as actual weight when soft tissues were present; when only hard parts were available, an estimated weight was given. For the time being, only prey composition was studied in the case of striped dolphin.

RESULTS In the stomach of three common dolphins, identified prey totalled more than 328 individuals belonging to four species of fish, two species of decapod crustaceans and seven species of cephalopods (Table 1). The stomach content of the female was the most abundant and suggestds, with its recently ingested prey, a complete meal. It was about two litres in volume, with a part consisting of a very dense suspension, which it was difficult to separate by filtration. The solid remains had the following approximate wet weights: 200 g crustaceans, 500 g fish, and 500 g cephalopods. The last two groups consisted of both recently ingested prey (450 g fish, 490 g cephalopods) and highly digested items like bones and beaks. Crustaceans, even when broken up into pieces had a "fresh appearance" and could be easily counted on the basis of pairs of eyes.

In the two males, the stomach content was less abundant with a lower number of species. Surface pelagic fish, anchovies and Belonidae, represented the total content in the first dolphin, while in the second dolphin, cephalopods of the families Onycoteuthidae and Ommastrephidae were dominant.

The gastric contents of the three striped dolphins will be described in detail elsewhere. Eight prey species were in common with common dolphin (Table 1), the largest ingested biomass resulting from *Pasiphaea multidentata* (two cases), and mesopelagic fish (one case).

DISCUSSION The stomach contents of common and striped dolphins reflect an offshore foraging method, which is only likely to affect fishing resources to a small extent. These two dolphin species are euryphagous predators which prey on fish, cephalopods and decapod crustaceans. This last prey is generally under-estimated in the analysis of stranded individuals; here, it forms the biggest portion in two of the four striped dolphins examined and also forms a major part of the stomach contents of the common dolphin. It is interesting to note that fishermen are not able to exploit the shrimps concerned.

Some common dolphin prey (*Belone* sp., *Chauliodus sloani, Sergia robusta, Onychoteuthis banksi*) have not been found in the present sample of striped dolphins; however, they were present in the stomach content of a specimen from the Ionian Sea (Bello, 1992) and, in stranded specimens from the Ligurian Sea (Wurtz and Marrale, 1991). Among "other prey" of striped dolphins examined here, crustacean decapods and cephalopods besides those listed in Table 2, are negligible. A larger share is formed by "other fish", mainly mesopelagic species (see also Miyazaki *et al.*, 1973) which, however, may be exploited also by common dolphin (Fitch & Brownell, 1968). Thus, the overall picture is of the two species feeding on the same prey and their trophic niches overlapping.

The distribution of prey can yield some useful information about the predatory habits of these dolphins. Besides surface pelagic fish such as *Engraulis encrasicholus* and Belonidae, all other prey consists of eurybathic species. The muscular squids *Ancistroteuthis lichtensteini, Onychoteuthis banksi,* and *Todarodes sagittatus* frequent surface waters during the night, as has been proved by direct observation and strandings (Torchio, 1966, Orsi Relini, 1990). Other squids - *Abralia veranyi, Histioteuthis bonnellii, Histioteuthis reversa* - which have ventral photophores, are true mesopelagic species. *A. veranyi*, however, can be found "at the bottom in bathyal and in midwater above slopes, sometimes at the surface" (Nesis, 1982). The same may be said for *Heteroteuthis dispar* (Orsi Relini, 1992). Large *Histioteuthidae* can also move to the surface (Torchio, 1966). So it is difficult to draw any conclusions about the diving range of dolphins from cephalopod prey type. Decapod crustaceans seem to be more useful indicators. In fact, both *Pasiphaea multidentata* and *Sergia robusta* are "deepwater species", generally found below a depth of 700 m during daylight hours. Considering their nocturnal ascent, *P. multidentata* can reach surface waters (Franqueville, 1971), but *S. robusta* is fished at a minimum depth of 200 m, and abundant catches are made at 450-500 m (Foxton, 1970). Taking into account the large size of the ingested specimens and their number, a deep, even if nocturnal, "search for shrimps" on the part of the common dolphin is quite probable.

CONCLUSIONS The stomach content of three adult common dolphins killed in the 1970's in the Gulf of Genoa included 328 food items belonging to the following categories of fish, decapod crustaceans and cephalopods: *Belone* sp., *Chauliodus sloani, Engraulis encrasicholus, Sygnathus phlegon, Pasiphaea multidentata, Sergia robusta, Abralia veranyi, Ancistroteuthis lichtensteini, Heteroteuthis dispar, Histioteuthis bonnellii, Histioteuthis reversa, Onychoteuthis banksi,* and *Todarodes sagittatus*. A comparison with the stomach content of some striped dolphins of the same size and caught in the same area shows that these dolphins use common prey. Commercially unexploited decapod crustaceans make up a considerable part of the diet.

REFERENCES

Bello, G. 1992. Stomach content of a specimen of *Stenella coeruleoalba* (Cetacea: Delphinidae) from the Ionian Sea. Atti Soc. It. Sc. Nat. (in press).

Fitch, J.E and Brownell, R.L. 1968. Fish otoliths in cetacean stomachs and their importance in interpreting feeding habits. J. Fish. Res. Bd. Canada, 25(12): 2561-2574.

Foxton, P. 1970. The vertical distribution of pelagic decapods (Crustacea: Natantia) collected on the second cruise 1965. II. The Penaeidea and general discussion. J. mar. biol. Ass. U.K., 50: 961-1000.

Franqueville, C. 1971. Macroplancton profond (invertebres) de la Mediterranee Nord-Occidentale. Tethys, 3 (1): 11-56.

Miyazaki, N., Kasuya, T. and Nishiwaki M. 1973. Food of *Stenella coeruleoalba.* Sci. Rep. Whales Res. Inst., 25: 265-275.

Nesis, K.N. 1982. *Cephalopods of the world.* [Engl. translation by B.S. Levitov 1987] T.F.H.

Norris, K.S. and Prescott, J.H. 1961. Observations on Pacific cetaceans of Californian and Mexican waters. University of California publication in Zoology, 63, 4: 291-402, pl. 27-41, 12 figs.

Orsi Relini, L. 1990. Field observation of young *Ommastrephes bartrami* in offshore waters in the Ligurian Sea. Rapp. Comm. int. Mer. Medit., 32(1), 243.

Orsi Relini, L. 1992. Notes on a pelagic sample of *Heteroteuthis dispar* (Cephalopoda, Sepiolidae) from the Ligurian Sea. Bull. Inst. Oceanogr. Monaco (in press).

Poggi, R. 1986. I Delphinidae fatti pervenire al Museo di Genova tra il 1914 ed il 1917 dal sindacato peschereccio ligure-sardo.Ann. Mus. Civ. Storia Naturale, 84: 1-11.

Torchio, M. 1966. Euribatia di Teutacei, spiaggiamenti ed apporto di acque di origine continentale. Atti Soc. It. Sc. Nat.,105 (4): 317-342.

Viale, D. 1985. Ecologie des cetaces en Mediterranee nord- occidentale: leur place dans l'ecosysteme. Oceanogr. Mar. Biol. Ann. Rev., 23: 491-571.

Watson, L. 1989. *Whales of the world.* Hutchinson. 302 pp.

Wurtz, M. and Marrale, D. 1991. On the stomach contents of striped dolphins (*Stenella coeruleolba,* Meyen 1933) from the Ligurian coast, central Mediterranean Sea. Pp. 62-64. In . *European Research on Cetaceans - 5.* (Ed. P.G.H.Evans). Proc. 5th Conf. ECS, Sandefjord, 21-23 February 1991. European Cetacean Society, Cambridge.

Table 1: Stomach content of three adult *D. delphis* and comparison with stomach contents of *Stenella coeruleoalba*.

	D. delphis female		D. delphis Male		D. delphis male		Stenella coeruleoalba		
	prey N.	Weight	N.	W.	N.	W.	female	male	male
OSTEICHTHYES									
Belone sp.			3	800					
Engraulis encrasicholus	40	450	60	660				*	
Sygnathus phlegon					1	10			
Chauliodus sloani	13	150							
mesopelagic fish n.e.i.							*		**
CRUSTACEA									
Pasiphaea multidentata	3	35					**	**	
Sergia robusta	99	160							
Decapoda n.e.i.									*
CEPHALOPODA									
Heteroteuthis dispar	58	195			1	4	*	*	*
Ancistroteuthis lichtensteini	30	1570			2	100		*	
Onychoteuthis banksi	5	95							
Histioteuthis bonnellii	1	5							*
Histioteuthis reversa	7	45						*	*
T. sagittatus - O. bartrami	9	3230			14	2842	*	*	
Abralia veranyi	2	5							
cephalopods n.e.i.							*	*	
	267	5940	63	1460	18	2956			

* presence and ** dominance of a given prey; n.e.i.= not elsewhere identified.

BENIGN RESEARCH ON MINKE WHALES OFF THE ISLAND OF MULL, SCOTLAND

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For the past three years, Sea Life Cruises have conducted commercial whale watching trips from the Island of Mull. During the summer of 1992, "Song of the whale" worked in the area in collaboration with Sea Life Cruises. Minke whales and harbour porpoises are seen very frequently whilst in descending order, other sightings of cetaceans include common dolphins, Risso's dolphins and killer whales. However, research was focused on the minke whales.

Very little non-lethal research has been conducted on minke whales from the North East Atlantic stock. As part of this project, which was funded by the International Fund for Animal Welfare, various techniques have been tested and their usefulness evaluated. Although considerable efforts were made to record minke vocalisations, no identifiable sounds were heard. Surfacing intervals for individual animals were recorded using simple stopwatches and event recording computers. Large numbers of photographs were taken of the flanks of minke whales with a view to the identification of individual animals using nicks on the dorsal fin and pigmentation marks on the flank. Additional information was obtained from sequential pictures taken using a motor drive. Although the majority of photographs are of limited usefulness, there were a number of re-sightings of individual animals both within and between years. As a part of the project, "Logger", a computer program that runs in real-time, was developed by Conservation Research Ltd. Logger is linked to a GPS satellite navigation system and records positional, environmental and effort status on a regular basis, together with preliminary results from the second half of the 1992 field season. Logger can be applied to research conducted from "platforms of opportunity".

THE DESIGN AND ANALYSIS OF SIGHTINGS SURVEYS FOR ASSESSING CETACEAN ABUNDANCE

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INTRODUCTION The abundance and distribution of many cetacean populations are substantially affected by man's activities, through past or present directed takes, through incidental takes in fishery operations, or through changes to the environment, ranging from a single pollution incident to global climate change. The importance of estimating abundance and distribution, and monitoring changes over time, is becoming increasingly apparent. Sightings surveys are widely considered to be the most reliable general method for estimating abundance. We review the fundamental issues of survey design and of the analysis of sightings data. More detailed information is given by Buckland *et al.* (1993).

SURVEY DESIGN The importance of good survey design is too often ignored. Cetacean sightings surveys are often expensive; to ensure that limited resources are used to greatest effect, it is essential that appropriate and accurate data are collected.

Choice of platform is often determined by costs, availability and practicality. However, platforms that prevent collection of reliable data should be ruled out, whatever their merits. For example, if survey conditions might be rough, a surface vessel should be sufficiently large to ensure a stable sighting platform. If an aircraft is used, the wings should be high, and it should have a clear 'bubble' at the nose, to ensure good visibility. Aircraft are generally only practical close to the coast, although helicopters are sometimes used in conjunction with ships.

Cruise tracks should be positioned to cover a representative sample of the study area. Where animal density is highly variable, stratification of the area, to allow more intensive effort where most animals occur, is important. Within each stratum, it is normal to place at random a grid of evenly spaced parallel lines. If animal density is known to depend strongly on distance from the shore, these lines should as far as possible be perpendicular to the coast. If line separation is large, use of parallel lines may be inefficient for surface vessels, due to the dead time between the end of one line and the start of the next. In this case, zig-zag patterns are often used.

Search effort may be carried out in either closing mode or passing mode. Difficulty in identifying species or in estimating school/herd/pod size often dictate that closing mode be adopted. For ship surveys in particular, closing mode can be costly, as the vessel stops active search effort before closing on a detection. Further, substantial bias in resulting abundance estimates is possible in some circumstances (for example in areas of high animal density).

A critical part of any sightings survey is the training of observers. It is obvious that inexperienced observers should be trained to enable them to identify species. Less obvious is that even experienced observers often are very poor at estimating sighting distances and angles, required for reliable estimation of abundance from shipboard surveys (Fig. 1). Even when observers are given the equipment to record angles precisely, many still persist in recording them to the nearest 5°, or even to the nearest 15°. Such inaccuracy severely compromises the data. Technical aids, such as reticles (graticules) in binoculars, angle rings on tripods or angle boards on ship rails, are an essential part of good survey methods. Distances estimated from aircraft are considerably more reliable if markers are positioned on the windows and wing struts, that indicate pre-determined distances when aligned.

Line Transect Analysis For line transect surveys of cetaceans, the critical data are the school encounter rate (number of schools n divided by transect length L), the distance y of each school from the line, and the size s of each detected school. Animal density D within the study area is then estimated as:

$$D = \frac{n}{L} \cdot \frac{1}{2\mu} \cdot E(s)$$

where $E(s)$ is the estimated mean school size and μ is the effective half-width of the strip searched. Effective half-width is estimated from the distances y; as many schools are detected at distances greater than μ. Poor survey design creates difficulty in estimating μ (Fig. 2). Population size is estimated as D multiplied by the size of the study area. A current research topic is the estimation of D as a function of geographic location.

One important assumption of the above method is that animals do not move in response to the observer prior to detection. Field methods should be designed with this requirement in mind. Another is that all animals on or close to the transect are detected. Often, for cetaceans, this assumption is not met; the issue of estimating the probability of detection on the track line is problematic. A method designed to address failures of both these key assumptions is summarised in Fig. 3.

Cue-counting Cue counting has similar design considerations as line transect sampling, and is sometimes carried out simultaneously with line transect sampling. An observer scans a sector ahead of the viewing platform (Fig. 4) and records the distance to each detected cue. The cue is usually defined to be a whale blow. Cues are recorded irrespective of whether the whale was previously detected, and it is not necessary to estimate school size. The method yields estimates of cue density, which can be converted into whale density by estimating the cue or blow rate from separate surveys. The observer records only radial distances. Perpendicular distances are not needed, and angles only determine whether a cue is within or outside the observation sector. To estimate cue rate, individual whales are followed, and the observed rate is used as an estimate of the cue rate for the whole population. This is the main weakness of the approach, as relatively few whales can be monitored for sufficiently long periods to obtain reasonable cue rate estimates. Further, these whales may not exhibit typical cue rates; for example, whales with high cue rates are less likely to be 'lost' before an estimate can be obained, and whales monitored over a long time period may change their cue rate in response to the vessel.

Migration Counts Some populations of cetaceans conveniently file past the coast during seasonal migration, allowing population abundance to be assessed from direct counts. Conceptually, this is quite different from line transect sampling, although similar methodology can be used to analyse the counts, by modelling time instead of distance. Typically there are regular, perhaps daily, counts of numbers of animals passing a watch point. If the animals pass in clusters, then the sampling unit is the cluster. The basic data are start and end times of watch periods and number of animals or clusters passing during each watch period. Thus the data are in frequency form, being grouped by watch period (Fig. 5). There are gaps between watch periods, corresponding to night or to poor weather. For the basic method, animals are assumed to migrate at the same rate during unwatched periods as during watches; the rate should be estimated by another method, for example by sonar (active or passive) or radar, or by radio-tagging animals, to adjust for different migration rate at night.

Mark-recapture At one time, it was thought that mark-recapture provided the only workable method for estimating the size of pelagic whale stocks. Marks were fired into whales, and stock size was estimated from the proportion of marked whales taken by whaling vessels. The method has had very limited success, because too many untestable assumptions must be made (Buckland and Duff, 1989). More recently, use of natural marks on flukes or the body and of DNA fingerprinting for individually identifying animals has received much attention. The methods are useful for providing estimates of mortality rate, but a large proportion of the population must be identified before reliable estimates of population size can be made. Extensions of mark-recapture models have application in line transect sampling when probability of detection on the line is less than one. Observations from two (or more) independent observers allow the probability to be estimated using mark-recapture methods.

Software Many complexities arise in the analysis of data from sightings surveys, and sophisticated software is required. Comprehensive analysis is now possible using DISTANCE (Laake *et al.*, 1993), pc-based software developed to implement the methodology described by Buckland *et al.* (1993). Its major features are summarised in Figure 6.

REFERENCES

Buckland, S.T., Anderson, D.R., Burnham, K.P. and Laake, J.L. 1993. *Distance Sampling: Estimating Abundance of Biological Populations*. Chapman and Hall, London.

Buckland, S.T. and Duff, E.I. 1989. Analysis of the Southern hemisphere minke whale mark-recovery data. Pp. 121-143. In *The Comprehensive Assessment of Whale Stocks: the early years.* (Ed. G.P. Donovan). International Whaling Commission, Cambridge.

Laake, J.L., Buckland, S.T., Anderson, D.R. and Burnham, K.P. 1993. *DISTANCE User's Guide.* Colorado Cooperative Fish and Wildlife Research Unit, Colorado State University, Fort Collins, CO 80523, USA.

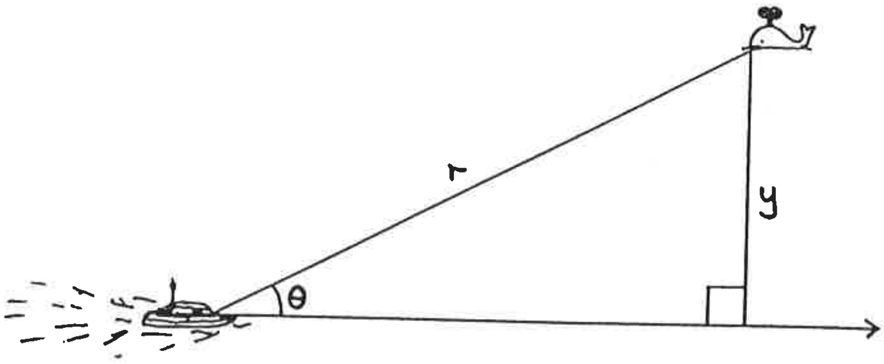

Fig. 1 Reliable line transect analysis requires that distances y are recorded accurately. In shipboard surveys, this is usually achieved by estimating the sighting distance r and sighting angle Ø , from which y is calculated as $y=r.\sin(Ø)$

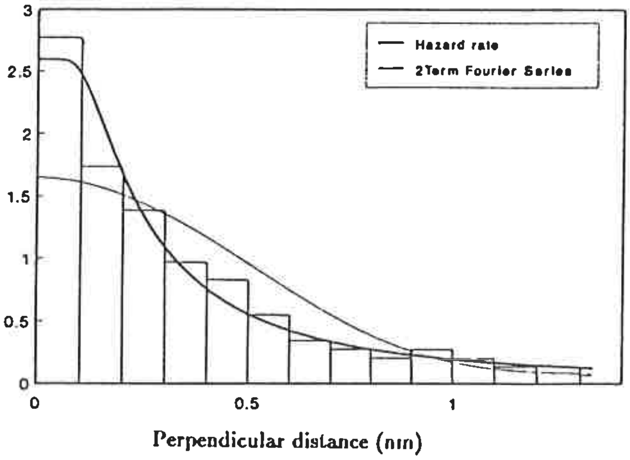

Fig. 2 Estimated density D of animals is proportional to the intercept ($1/\mu$) of the fitted density function of particular distances with the y-axis. When detection probability falls quickly with distance from the line, this intercept can depend strongly on the choice of model

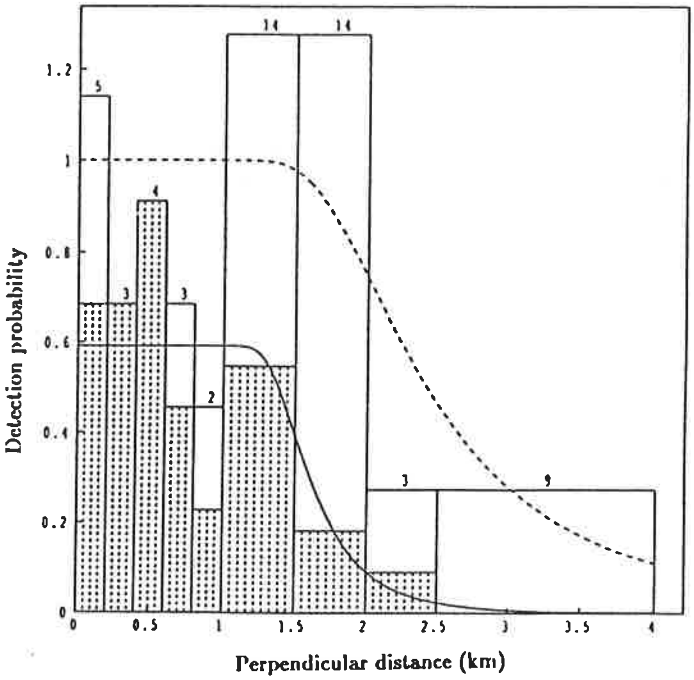

Fig. 3 Histogram of numbers of Dall's porpoise schools detected by a helicopter moving ahead of the survey ship. Shading indicates which schools were subsequently recorded by the ship. These data allow the density estimate to be corrected for responsive movement of porpoise to the vessel and for failure to detect all porpoise close to the transect line

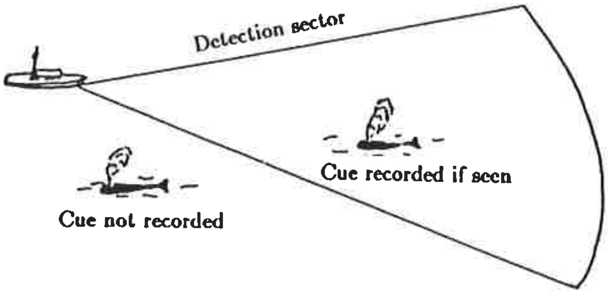

Fig. 4 For the cue counting method, all cues detected by the observer within the observation sector, and their distances from the observer, are recorded

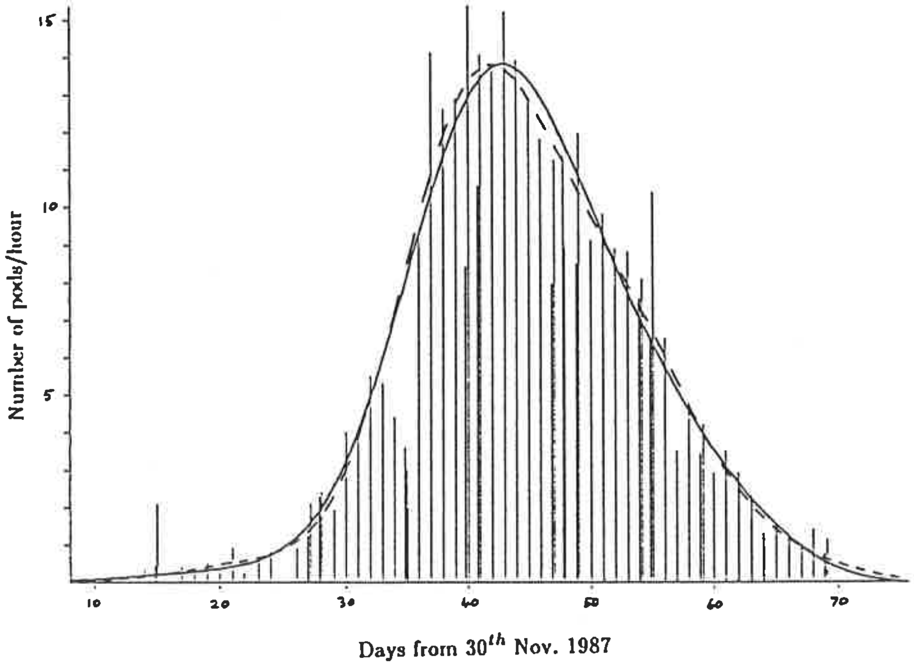

Fig. 5 Histogram of number of grey whales per hour passing Monterey. Also shown are fits of the Hermite polynomial model to the migration counts. These fits allow the number of whales counted to be converted to an estimate of the total number passing Monterey during the migration

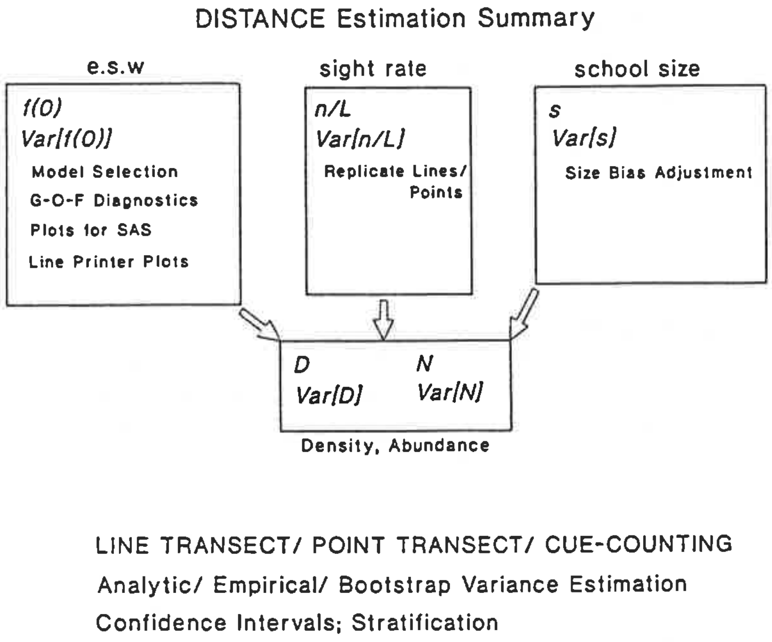

Fig. 6 Summary of the main features of the software DISTANCE

SEA MAMMAL OBSERVATIONS ON FRANZ JOSEF LAND

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Since the opening for Russian scientists, the Russian arctic archipelago was visited by three following Russian-Norwegian-Polish summer expeditions in 1990, 1991, and 1992.

Part of the scientific programme was devoted for the preparation of a map presenting the recent status of sea mammals of Franz Josef Land archipelago. Four whale and five pinniped species have been observed. Bowhead whales were observed twice in the southern part of the archipelago; the most common were walruses found all over the area.

MARINE MAMMAL AND SEABIRD OBSERVATIONS OFF SPITSBERGEN, 1991

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During the oceanographic expedition AREX-91 with r/v Oceania of the Polish Academy of Sciences, marine mammals and seabirds were counted systematically in the western Barents Sea and the North Atlantic Ocean. Observations were made between 24 June and 11 July, 1991.

Between north Norway and Spitsbergen, the white-beaked dolphin (*Lagenorhynchus albirostris*) was the most frequently observed cetacean species. Pod size varied between three and twenty. The total number observed, north-west of Bear Island was estimated between 85 and 107 individuals. The dolphins were swimming in water with depths between 200 and 1,000 m, along the continental slope.

The distribution of plankton and of animals depending on this resource in Arctic Seas, is patchy and highly seasonal. The largest biomass can be found in the upwelling zones (the ocean fronts). These upwelling zones occur where Atlantic and Polar waters (of differing temperatures and salinities) meet. Between Spitsbergen and Bear Island, it follows roughly the edges of the continental shelf (the 200m contour line).

Marine mammals and seabirds approach the front from different directions. Birds are strongly bound to the coast and their breeding colonies during the breeding season, and have a limited range from the colony. Marine mammals can use the total space.

Physical conditions of the marine environment can explain a significant proportion of the variation in seabird distribution. The spots where oceanic fronts were present usually had the highest bird densities. All those were over the continental shelf around Spitsbergen. Birds prefer, for obvious reasons, to exploit the coastal side of the polar front. Whales and dolphins seemed to prefer the side of the polar front closer to the continental slope.

SURVEY OF CETACEANS IN THE MINCHES AND SEA OF HEBRIDES, NORTHWEST SCOTLAND

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INTRODUCTION The Minches & Sea of Hebrides off the northwest coast of Scotland are amongst the most productive of marine areas in Britain. The warm waters of the Gulf Stream and cooler coastal tidal streams which flow past the offshore islands provide suitable habitats for a variety of cetaceans. The purpose of this project was to survey the region for cetaceans, investigate geographical and seasonal variation in abundance, and identify any important areas. At a later stage, when sufficient data have been collected, estimates of population densities and thence overall population sizes will be made for the commoner species.

METHODS Surveys were conducted aboard the 80ft gaff-rigged yacht, "Marguerite Explorer" using line transect techniques. Pre-determined routes, bisecting the region, were transected repeatedly through the summer (June - August) of 1992. No transect was started in conditions greater than sea state 2. Those transects were supplemented by a number of journeys to sample inshore areas in more detail (Fig. 1). Every 30 mins, the ship's position, course, and speed together with various environmental parameters were recorded. A constant watch was kept for cetaceans and all sightings noted, together with their position, group size, behaviour, and associated environmental conditions. The perpendicular distance of each sighting from the track-line was determined using either calipers or an optical rangefinder, in combination with a digital sighting compass. For the present purpose, sightings rates were calculated on the basis of distance travelled, but in due course when sufficient data are collected, it will be possible to fit curves of detectability for each species for various sea states, and to derive estimates of population density and thence population size in the region.

RESULTS A total of 216 sightings comprising 748 individuals of six cetacean species were recorded during the period of the survey. Seasonal changes in sightings frequency are presented in Fig. 2, and a summary of survey effort numbers of individuals sighted by species in Table 1 for each grid cell (30' lat. by 1° long.).

Minke whales (*Balaenoptera acutorostrata*) were recorded throughout the region under study, but with sightings concentrated between Coll and Skye particularly around the Small Isles, in the Sounds of Harris and Barra, and west of Gairloch and Rubha Réidh. A total of 25 sightings were made during the survey. The great majority were sightings of single animals (mean group size = 1.16), with a maximum group size of four individuals. Sightings frequency increased to a peak in the first half of August.

Harbour porpoises (*Phocoena phocoena*) were the most frequently encountered cetacean, with 143 sightings comprising 244 individuals, albeit not as numerically abundant as common dolphins, Most harbour porpoises were encountered either singly or in pairs (modal group size = 1, mean group size = 1.71). They were widely distributed, particularly along the Scottish mainland coast and around the islands of Skye and Mull, and the Small Isles. They were less common in the western sectors of the Minches and Sea of Hebrides. Numbers of harbour porpoises reached a peaked in the first half of August, declining thereafter.

Common dolphins (*Delphinus delphis*) were the most abundant cetacean species recorded, with 17 sightings comprising 315 individuals. Most sightings were of groups of 6-10 indivs. (mean group size = 18.53) and largely confined to the waters south of the Isle of Skye, particularly the eastern Sea of Hebrides. 77% of sightings occurred in July, with very few after the end of that month. Only 2.2% of the common dolphins sighted were north of latitude 57°30' N. By contrast, **white-beaked dolphins** (*Lagenorhynchus albirostris*) were recorded mainly in the North Minches and the western Sea of Hebrides, with 84.5% (of 97 indivs. sighted), occurring there. Most sightings were of groups of 2-5 individuals (mean group size = 6.06). White-beaked dolphins were most common in August (84.5% of sightings of this species), with only 5.1% of sightings in July. **Risso's dolphins** (*Grampus griseus*) were relatively uncommon, with 13 sightings of 57 individuals. They were most frequently observed in groups of 2-5 (mean group size = 4.38) and were most abundant in August. They tended to be found in particular locations such as Tiumpan Head, NE of Stornoway, Isle of Lewis, and the east coasts of Coll and Tiree. Photo-ID studies revealed the presence of recognisable individuals repeatedly in a single location (around Tiumpan Head), but with at least two animals re-sighted 95 km from their first sighting.

Two sightings of **killer whales** were made during the study, one of a pod of four animals (two mature males, a female or subadult, and a juvenile) seen near the Treshnish Islands in late July, and two killer whales (an adult male and a juvenile) seen in late August west of the island of Canna. The latter male killer whale was one of the adult males from the previously sighted pod, having a distinctive large nick out of the centre of the trailing edge of its dorsal fin. This animal and another male with a distinctly bent fin have been sighted in the region a number of times over the last few years, indicating consistent use of an area south and west of the Isle of Skye, particularly west of Canna south past Haskeir rock to Coll, Tiree and the Treshnish Isles (Fig. 3). The greatest distance for sightings of a particular individual within years was 85 km, and between years was 160 km.

DISCUSSION The Hebrides is an area of outstanding scientific interest because of its geographical position at the extreme western edge of the European continent and the north-western tip of Britain. High marine productivity occurs in those areas where water with different properties interface to form fronts (Pingree & Griffiths 1978). Waters around islands that enhance mixing are often enriched, leading to nearshore fronts with high plankton productivity such as around Barra Head (Savidge & Lennon, 1987). Strong tidal streams passing over a complex bottom as occur around the islands of Rum, Eigg, and Canna also result in nutrient upwellings leading to plankton concentrations. Fish respond to such aggregations of their prey, occurring in large numbers in downstream eddies behind islands, and this in turn attracts cetaceans.

The distribution of fish west of Scotland during summer probably has a major influence on the distribution of most cetacean species occurring in the region. Young whiting (*Merlangius merlangus*) are abundant throughout the Minches in summer. Sprat (*Sprattus sprattus*) are dispersed nearshore in summer, spawning in June throughout the region but particularly in the north Minches and north of the Butt of Lewis. On the other hand, gadoid fish like cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*), saithe (*Pollachius virens*), Norway pout (*Trisopterus esmarkii*), and whiting have important spawning grounds west of the Isle of Lewis (Lee & Ramster, 1981). Sandeels (mainly *Ammodytes marinus*) are abundant in shallow shelf seas west of mainland Scotland between February and July. An industrial fishery for sandeels has been operating since the mid-1980's off the Butt of Lewis with a marked increase in annual catches and fears that stocks may be over-exploited (Boyd & Boyd, 1990). Most herring (*Clupea harengus*) spawn between late August and early October, on gravel beds to the west and north of Tiree, in the northern Minches near Cape Wrath, and north and west of the Outer Hebrides, mainly within 20-30 miles of the coast. Those Hebridean waters also form important nursery areas for herring many of which then drift north-east or eastwards into the North Sea.

In recent years, the largest whitefish fishery in Hebridean waters has been for mackerel (*Scomber scombrus*). These migrate along the edge of the continental shelf west of the Outer Hebrides between their spawning grounds west of Ireland and northern feeding grounds .

During the late 1970's and the early 1980's, there was a very large fishery in the North Minches with mackerel processing ships occupying Loch Broom in autumn and winter. At that time, large schools of white-beaked dolphins were commonly observed closely associating with the mackerel shoals (Evans, 1981). However, since the mid-1970's, the autumn fishery has steadily shifted northwards and the timing become progressively later, attributed to a long-term reduction in the flow of Atlantic water west of Scotland and into the North Sea during the period 1960-80, and an increase of this flow in later years (Walsh & Martin, 1986). This might also explain the apparent recent northward extension in range of two typically warm water species, the common and striped dolphins (Evans, 1992), both of which have been recorded recently in North Scotland. It may further explain the low number of white-beaked dolphins observed in the region between June and Sept 1992 compared with July - Sept 1980 (Evans, 1981). During the cruises conducted in summer 1980, no common dolphins were observed north of 56°N, whereas in summer 1992, they were abundant at a latitude of 58°N at least until mid-July.

Harbour porpoises were seen in Hebridean waters in greatest numbers during the first half of August at a time when sprat and whiting are abundant but other fish such as herring and mackerel are still present in only low numbers, and sandeels are starting to burrow into the sand. Saithe and Norway pout also occur in numbers during this period, but are concentrated more in the north Minches and to the west of the Hebrides than in those areas where most porpoises were seen. Minke whales were present throughout the summer but, during early August, were observed lunge-feeding on surface sprat and herring in close association with feeding aggregations of Manx shearwaters (*Puffinus puffinus*), and sometimes also porpoises.

Killer whales are observed regularly in the Minches and Sea of Hebrides between May and September (Evans 1988, 1992). Recognisable individuals have been seen repeatedly in particular localities, notably west of Canna southwards towards Coll, Tiree and the Treshnish Isles. Those are all areas with important breeding populations of Atlantic grey seal (*Halichoerus grypus*), and harbour seal (*Phoca vitulina*), and killer whales have been observed attacking seals in the region at that time (Evans, 1988). On the other hand, both herring (*Clupea harengus*) and salmon (*Salmo salar*), important prey of killer whales elsewhere, are also common in the region. Salmon return to the rivers of the Hebrides from late February into the summer, usually peaking in numbers in July. Herring become abundant rather later, in August through to November. We are not in a position yet to say what is the main diet of killer whales in the area or to understand the factors determining their seasonal distribution. Squid such as *Loligo forbesi* migrate inshore in late summer and early autumn before spawning between December and March. Risso's dolphins feed primarily upon squid but are present throughout the summer along the slope that borders the Hebrides, at depths between 50 and 100 metres. Their numbers also reach a maximum during August and September, in line with our present knowledge of the ecology of their cephalopod prey.

CONCLUSIONS Surveys of the Minches and Sea of Hebrides have reinforced earlier information indicating the richness of this area for cetaceans. Commonest species were harbour porpoise and common dolphin, although the former was not abundant until early August, and the latter became scarce by late July. Common dolphins were rare north of the Isle of Skye, their place being taken by white-beaked dolphins which more or less displaced that species in its distribution. Risso's dolphins were uncommon in the region, but occurred regularly in particular localities such as around Tiumpan Head, Isle of Lewis and along the east coasts of Coll and Tiree. Minke whales were frequently seen but only in small numbers. Although widely distributed, the species was mainly observed in areas with strong tidal currents, such as the sounds between Coll and Skye and around the Small Isles, and the Sounds of Harris and Barra. Killer whales were scarce, but a review of sightings of two recognisable individuals indicated consistent use over a number of years of an area south and west of the Isle of Skye, particularly west of Canna southwards towards Coll, Tiree and the Treshnish Isles.

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REFERENCES

Boyd, J.M. and Boyd, I.L. 1990. *The Hebrides.* Collins, London. 416 pp.

Evans, P.G.H. (editor) 1981. *Report of N.E. Atlantic Scientific Cruise, 1980.* Occasional Publication, Mammal Society, London. 24pp.

Evans, P.G.H. 1988. Killer whales (*Orcinus orca*) in British and Irish waters. Rit Fiskideildar, 11: 42-54.

Evans, P.G.H. 1992. *Status Review of Cetaceans in British and Irish waters.* Final Report to Department of the Environment, London. 98pp.

Lee A.J. and Ramster, J.W. 1981. *Atlas of the seas around the British Isles.* Ministry of Agriculture, Fisheries and Food, London.

Pingree, R.D. and Griffiths, D.K. 1978. Tidal fronts on the shelf seas around the British Isles. J. Geophys. Res., 83: 4615-4622.

Savidge, G. and Lennon, H.J. 1987. Hydrography and phytoplankton distributions in north-west Scottish waters. Contin. Shelf Res., 7: 45-66

Walsh, M. and Martin, J.H.A. 1986. Recent changes in the distribution and migrations of the western mackerel stock in relation to hydrographic changes. ICES C.M. 1986/H:17, 19pp.

Table 1 Distribution of survey effort and numbers of individuals recorded per km travelled for various cetacean species

Kilometres Travelled

	5°W-5°59'W	6°W-6°59'W	7°W-7°59'W
56°00'N-56°29'N	253.45	81.40	0.00
56°30'N-56°59'N	295.30	1114.63	284.90
57°00'N-57°29'N	271.03	419.03	250.68
57°30'N-57°59'N	221.08	246.98	14.80
58°00'N-58°29'N	269.18	128.58	0.00

Number of Harbour Porpoise Individuals Sighted

	5°W-5°59'W	6°W-6°59'W	7°W-7°59'W
56°00'N-56°29'N	3	4	0
56°30'N-56°59'N	21	47	13
57°00'N-57°29'N	18	49	3
57°30'N-57°59'N	57	4	0
58°00'N-58°29'N	6	15	0

Number of Common Dolphin Individuals Sighted

	5°W-5°59'W	6°W-6°59'W	7°W-7°59'W
56°00'N-56°29'N	0	0	0
56°30'N-56°59'N	0	322	0
57°00'N-57°29'N	0	28	5
57°30'N-57°59'N	0	2	0
58°00'N-58°29'N	0	5	0

Number of White-Beaked Dolphin Individuals Sighted

	5°W-5°59'W	6°W-6°59'W	7°W-7°59'W
56°00'N-56°29'N	0	3	0
56°30'N-56°59'N	0	0	10
57°00'N-57°29'N	0	0	11
57°30'N-57°59'N	0	2	0
58°00'N-58°29'N	75	5	0

Number of Risso's Dolphin Individuals Sighted

	5°W-5°59'W	6°W-6°59'W	7°W-7°59'W
56°00'N-56°29'N	0	0	0
56°30'N-56°59'N	0	15	0
57°00'N-57°29'N	0	3	12
57°30'N-57°59'N	0	0	0
58°00'N-58°29'N	5	21	0

Number of Minke Whale Individuals Sighted

	5°W-5°59'W	6°W-6°59'W	7°W-7°59'W
56°00'N-56°29'N	0	0	0
56°30'N-56°59'N	0	9	0
57°00'N-57°29'N	0	3	2
57°30'N-57°59'N	6	6	0
58°00'N-58°29'N	1	2	0

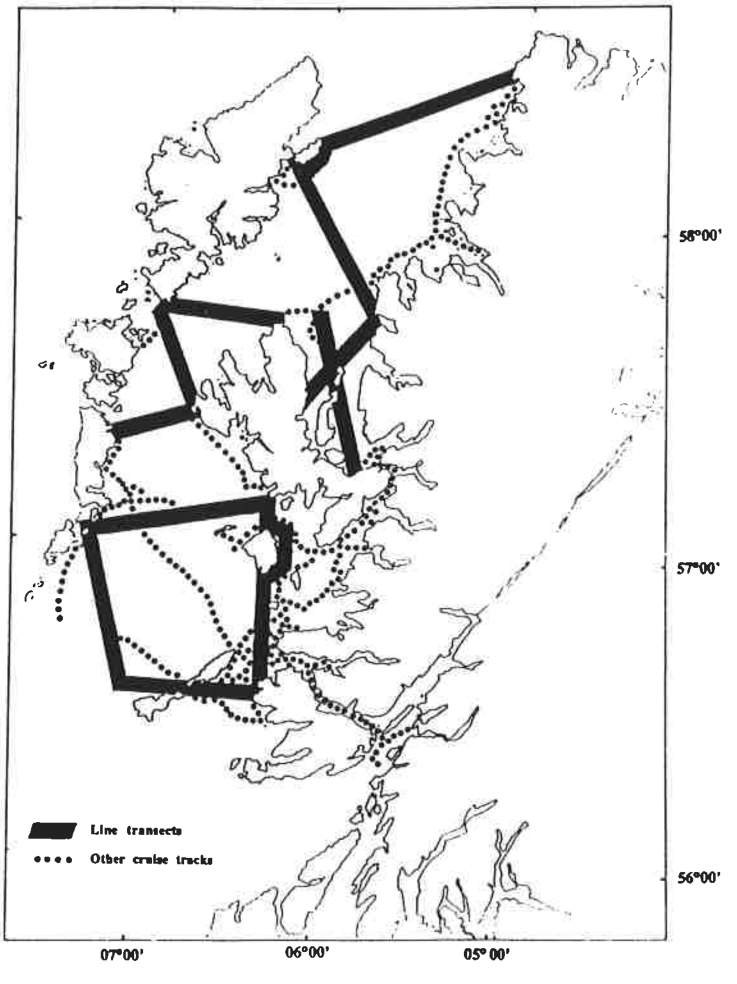


Fig. 1 Map of line transects and other cruise routes in the Hebrides, June - August 1992

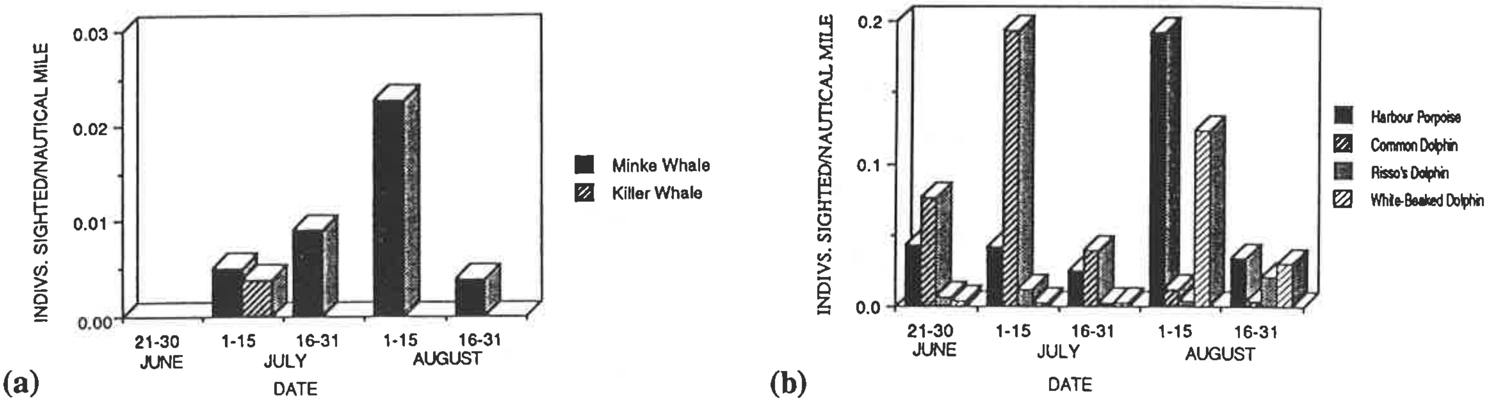
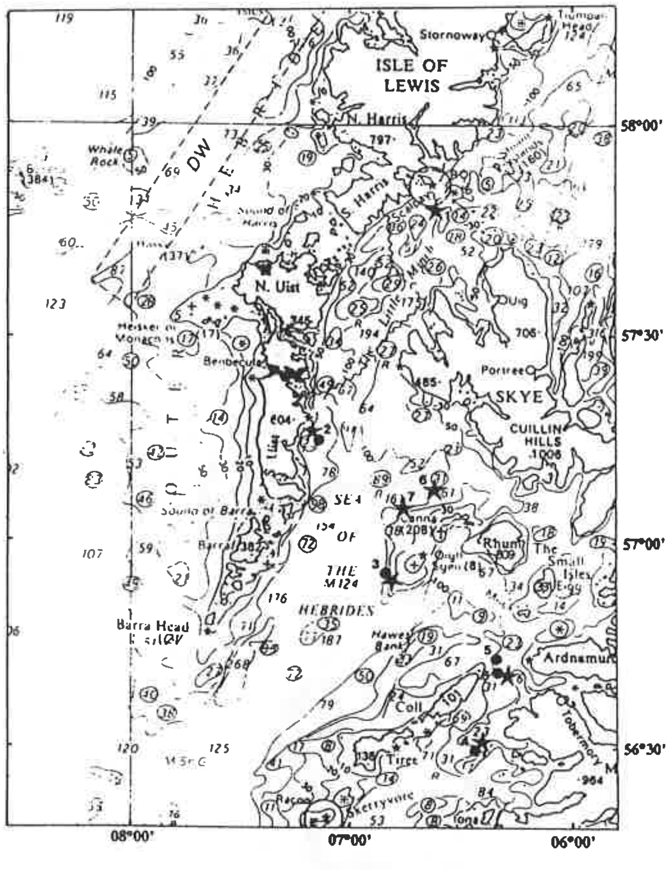


Fig. 2 Temporal changes in abundance of (a) whales and (b) dolphins & porpoises in Hebridean Waters



Encounter No.	Date	Indiv. No.	Group Size
1	29-5-87	A	c.20
2	23-5-91	A & B	c.20
3	8-9-91	A & B	5-6
4	15-7-92	A & B	4
5	28-8-92	B	2
6/7	2-9-92	A	2
8	23-9-92	A & B	7

★ Indiv. A ("John Coe")

● Indiv. B ("Floppy Fin")

Fig. 3 Map showing distribution of sightings of two identifiable killer whales

FINDINGS FROM CETACEAN SURVEYS OFF THE WEST COAST OF SCOTLAND DURING 1992

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INTRODUCTION There is little information about the presence and abundance of cetaceans off the west coast of Scotland although there is obviously a rich variety (Evans, 1987; Klinowska, 1991). There is also little public awareness of their presence, no conservation measures, and relatively little research on the status of these species and the threats they face.

The MV Solo cetacean sightings surveys aimed to document the presence and distribution of cetaceans off the west coast of Scotland. The first survey was designed to cover areas of changing bottom topography off the north-west coast of Scotland. Evans (1990) considers that the upwelling which occurs in such regions improve the supply of nutrients to plankton and the whole marine food web. The second survey took place in the more sheltered waters off the south-west coast of Scotland and the Firth of Clyde.

METHODS

Survey Route The tracks of the two MV Solo surveys are shown in Figures 1 and 2. The first survey took place between 11-19 May and extended offshore from the north-west coast of Scotland. The second, between 21-26 June, covered more coastal waters off southwest Scotland.

Observations There were two teams of four observers with alternate watch periods of two hours. On sighting a cetacean, the time and location were recorded. If identification of the species was not immediately possible, the animals were approached to attempt to confirm identification. Behavioural and environmental data were also recorded.

RESULTS

Survey 1: Sightings During 129 hours of observation, there were a total of 24 cetacean sightings. Table 1 and Figure 1 give the details of sightings. Where a confirmed identification was not possible, the sighting is given as "baleen whale" or "small cetacean".

The only area where a concentration of one species was seen was in the North Minch, where five of the seven sightings of Risso's dolphins (*Grampus griseus*) were made. Sighting conditions were particularly good during this period (sea state 0).

Survey 1: Sea state and sighting efficiency Table 2 shows the distribution of sightings in relation to sea state. Although only 49% of the effort was during sea state 0-2, 82% of the sightings were made during this period. Because of the poor conditions, sightings are likely to have been artificially low.

Survey 2: Sightings During 79.5 hours of observation, there were nine sightings of cetaceans. Table 3 and Figure 2 give the details of the sightings.

During the time spent in the Firth of Clyde, sea state was never above 3. Therefore, the paucity of sightings must reflect a low abundance of cetaceans in this region at this time of year.

If the sightings rates are compared between surveys at sea state below 3, there was a higher frequency on survey 1 with 0.32 sightings per hour effort compared with 0.13 sightings per hour effort on survey 2.

CONCLUSIONS The surveys demonstrated the rich variety of cetacean species which are present off the west coast of Scotland. Seven species were identified in total - two baleen whales and five small cetaceans. In agreement with Gunnlaugsson & Sigurjonsson (1990), weather conditions had a dramatic effect on sighting efficiency, and observations made during sea states of three or greater were almost completely unproductive. These poor conditions coincided with periods spent in the off-shore areas. Therefore it is difficult to conclude whether the sudden abundance of sightings east of the Outer Hebrides reflects a more productive nature of the area or the sighting conditions during that period. However, Evans (1990) also suggests the area is important for small cetaceans.

The Firth of Clyde was covered comprehensively during the second survey and there were no sightings of cetaceans during that period in June, although Evans (1990) reports it to be an area of abundance for harbour porpoises (*Phocoena phocoena*) later in the year, during August-October.

Detailed information on the population size and viability, behaviour and ecology of any of the species seen is still unavailable. There is a need to protect and further study cetaceans in British waters and the threats they face.

REFERENCES

Cater, B, 1991 The little leviathans. BBC Wildlife 9:712-718

Evans, P.G.H. 1987 *The natural history of whales and dolphins.* Christopher Helm, London.

Evans, P.G.H. 1990 European cetaceans in an oceanographic context. Lutra 2: 95-125

Gunnlaugsson, T. & Sigurjonsson, J. 1990 NASS-87: Estimation of whale abundance based on observations made on board Icelandic and Faroese survey vessels. Rep. Int. Whal. Commn. 40: 571-580

Klinowska, M. 1991 *Dolphins, porpoises and whales of the world.* The IUCN Red Data Book. IUCN, Cambridge, UK. 429pp.

Table 1 The species and the group size ranges seen during the first survey

SPECIES	N0. OF SIGHTINGS	GROUP SIZE
Risso's dolphin	7	3-35
Harbour porpoise	5	1- 3
White beaked dolphin	2	1- 2
Common dolphin	1	15-20
Long-finned pilot whale	1	18
Fin whale	1	3
"Baleen whale"	3	
"Small cetacean"	4	

Table 2 The number of sightings in relation to sea state (Beaufort scale) during survey 1.

SEA STATE	EFFORT (hours)	% TOTAL EFFORT	NO. OF SIGHTINGS	% TOTAL SIGHTINGS
0	18.95	14.7	9	37.5
1	33.15	25.7	8	33.3
2	11.00	8.5	3	12.5
3	21.60	16.8	1	4.2
4	12.25	9.5	3	12.5
5+	32.00	24.8	0	0.0

Table 3 The species and the group size ranges seen during the second survey

SPECIES	NO. OF SIGHTINGS	GROUP SIZE
Harbour porpoise	2	1- 2
Common dolphin	3	1-18
Minke whale	2	4- 6
"Baleen whale"	1	
"Small cetacean"	1	

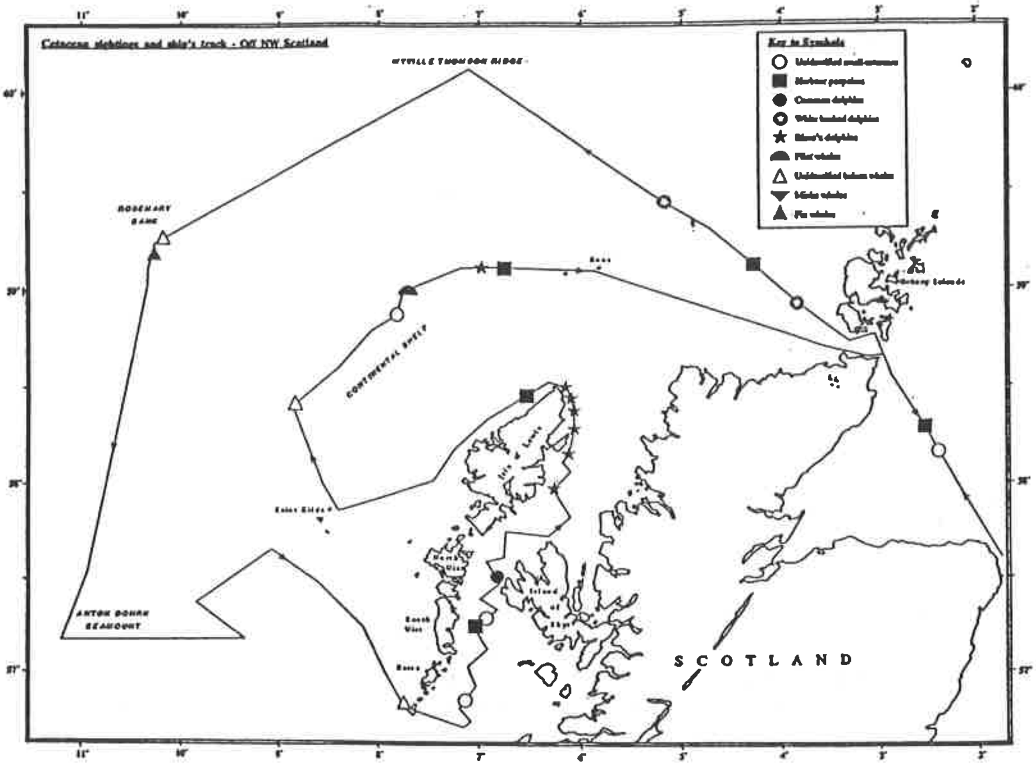

Fig. 1 Cetacean sightings and ship's track - off North West Scotland

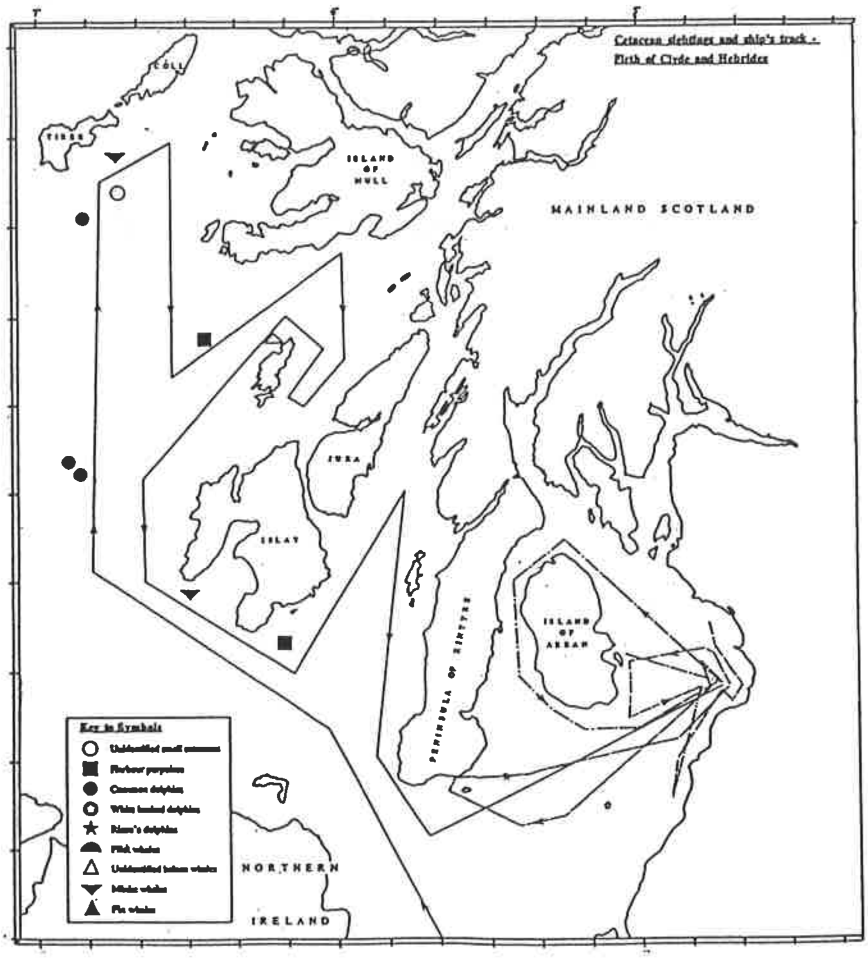

Fig. 2 Cetacean sightings and ship's track - Firth of Clyde and Hebrides

CONSTANT EFFORT CETACEAN SIGHTINGS SURVEY OF IRELAND

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Twenty-six headlands around the coast of Ireland were visited between 17 September and 24 October, 1992. At each site, the sea was surveyed for cetaceans for 100 minutes. Whenever possible, sites were only visited when the sea was sea state 2 or less.

No cetaceans were recorded along the north or east coasts of Ireland, but they were recorded at 40% of sites visited on the west and south-west coasts. A total of 15 sightings were made during the survey including harbour porpoise (*Phocoena phocoena*), Common (*Delphinus delphis*), Risso's (*Grampus griseus*), and Bottle-nosed dolphins (*Tursiops truncatus*), and minke whales (*Balaenoptera acutorostrata*).

Harbour porpoise were the most frequently recorded species occurring at four sites in groups of 1-5 individuals, including a calf at Slea Head, County Kerry. Single minke whales were seen at three sites; common dolphins at two, including calves in a group of 50-60 off Mizen head, County Cork; and Risso's and Bottle-nosed dolphins were recorded each at one site. The sighting rate was calculated at one sighting per 173 minutes for Ireland as a whole and one sighting per 114 minutes for the west and south-west coasts.

This survey was funded by the Robert Lloyd Praeger fund of the Royal Irish Academy, Dublin.

INVESTIGATIONS ON THE ABUNDANCE, HEALTH STATUS, AND MIGRATION OF SMALL CETACEAN POPULATIONS IN GERMAN WATERS

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The number of small cetaceans in German waters, particularly harbour porpoises (*Phocoena phocoena*), has drastically declined in the past few decades. Insufficient knowledge exists regarding the number, distribution and migratory behaviour of these populations. Even less knowledge exists about the reasons for their decline. This project is part of an international initiative to fill the gaps in our knowledge. It also establishes the bases of protective measures to be taken.

Sightings All incidental sightings in German waters were gathered and processed at the Forschungs und Technologiezentrum Westküste (FTZ), University of Kiel. In addition to the incidental sightings, aerial surveys were conducted in certain regions during 1991 and 1992. These surveys were made possible with the co-operation of Danish colleagues.

Strandings All strandings on the German coasts were centrally registered in FTZ. The harbour porpoises comprised the majority of strandings (1990: 76/81; 1991: 101/104). Strandings of white-beaked dolphins (*Lagenorhynchus albirostris*) Atlantic white-sided dolphins (*Lagenorhynchus acutus*), bottle-nosed dolphins (*Tursiops truncatus*) and common dolphins were comparatively rare. A network of 27 facilities was established where thr carcasses (*Delphinus delphis*) were kept frozen before being transported to the institute for further study. A reward of 50 DM was given to those finding a small cetacean in compensation for its delivery.

By-catches Fishers from Schleswig-Holstein were responsible for most of the harbour porpoise by-catches in German waters (1990: 21; 1991: 29). The fishers also received 50 DM for the delivery of the animals.

Postmortem and sample taking Strandings and by-catches from Schleswig-Holstein were examined both zoologically and in a veterinary context. Further examination for histopathology, parasitology, virology and bacteriology were co-ordinated from the Institut für Veterinär-Pathologie, University of Giesen. Samples were also taken for further studies of age determination, nutrition, reproductive biology and toxicology.

HARBOUR PORPOISE (*Phocoena phocoena*) DENSITIES OBTAINED FROM AERIAL SURVEYS AROUND THE ISLE OF FYN, IN THE BAY OF KIEL, AND IN AN AREA NORTH-WEST OF SYLT

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Aerial surveys of harbour porpoises (*Phocoena phocoena*) were conducted in June-July, 1991 and 1992 under optimal sighting conditions in an area north of Fyn, the Great Belt, Little Belt, in the Bay of Kiel and north-west of Sylt. Density of pods of porpoises was estimated by use of line-transect theory, utilising measurements of perpendicular distances of sightings and fitting the probability density function by a hazard rate model. The survey results were compared for the two years.

The highest densities of porpoises was found in the North Sea area, whereas the Bay of Kiel and the Little Belt had low densities of porpoises. The Great Belt and the area north of Fyn had intermediate densities and the area north of Fyn had a density similar to what was found in the same area in 1991. The perpendicular distance distribution of sightings from the surveys in 1991 and 1992 were identical in locality and dispersal, but gave rise to different estimates of effective search widths. Pod sizes for the 1992 survey were lower than pod sizes collected from boat surveys, but were within the range of pod sizes determined from the surveys in 1991.

No corrections were applied for submerged porpoises. Strip census methods were not applicable to harbour porpoise surveys because of the width of the strip where an equal detection probability can be assumed to be unacceptably narrow. It is recommended that future surveys should be conducted at an altitude of 183m (600feet) and that line transect methods should be applied.

CETACEAN FREQUENCY, DISTRIBUTION AND CO-PRESENCE WITH OTHER SPECIES IN THE BAY OF BISCAY FROM "CETACEA-92"

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INTRODUCTION Since 1990, the Maritime Museum of the Cantabric initiated, and the Complutense Madrid University continued, conducting a cetacean survey in the Bay of Biscay from data recorded in commercial tuna live-bait vessels. A joint program with the Spanish Institute of Oceanography provided the means by which the cruise "Cetacea-92" could be carried out.

METHODS In 1992, the search platform was the tuna vessel "Mater" from Getaria (Guipozoka) of 30 metres in length. The cruise began on 4 July and ended on 26 September with 4,730 nautical miles of search effort, from 43°43'N to 48°52'N latitude and from 2°30'W and 20°40'W longitude in the Bay of Biscay and neighbouring Atlantic waters. Due to the data being collected during the fishing activities, the zone covered includes the area where fishermen estimate the probable presence of tuna shoals.

In the Bay of Biscay, the tuna fishermen use observations of breaching dolphins as a visual cue for the detection of tuna shoals, five to nine men continuously scan from the bow at a height of about 3 m., and from the platform mast at about 6m height.

RESULTS AND DISCUSSION As in previous surveys, the most frequent species were fin whales (*Balaenoptera physalus*) (Table 1) and common dolphins (*Delphinus delphis*) (Table 3). Contrary to the results obtained during CETACEA-91 cruises (Garcia-Castrillo and Güemes, 1992), in this survey long-finned pilot whales (*Globicephala melas*), were sighted but not Risso's dolphins *Grampus griseus.* This could be due to the distribution of effort (Fig. 1), which this year centred on pelagic areas, whilst in 1991 it was centred on near-shore areas, corresponding with their respective habits.

It is surprising that for the third consecutive year, only one solitary male killer whale (*Orcinus orca*) has been sighted (Table 2). Two pairs of harbour porpoise (*Phocoena phocoena*) were observed (Table 3), whereas none occurred in previous surveys.

The distribution of fin whale sightings (Fig. 2) confirms the connection between the Atlantic Iberian stock (Lens, 1991) and the summer concentration in the Bay of Biscay (Güemes and Garcia-Castrillo, 1992).

The average sightings frequency per square for fin whale is higher in the Atlantic area than in the Bay of Biscay (Table 4). The corresponding values in the Bay of Biscay was 1.42 schools/100nm during CETACEA-91 and 1.38 schools/100nm for CETACEA-92, indicating similar summer concentrations between years. On the other hand, the sightings frequency of common dolphin is higher in the Bay of Biscay than in the Atlantic area (Table 5).

Although in CETACEA-90 and CETACEA-91, we used the term association to refer to relations between other animal species, here we use the term "co-presence" to represent the simultaneous presence of two species that may or may not be associated. The highest proportion of co-presence occurs with the great shearwater (*Calonectris diomedea*), invariably in the Atlantic area. Common dolphins also showed a high presence with northern gannets (*Sula bassana*) in the Bay of Biscay. Tuna showed co-presence with fin whales in the Atlantic area and Bay of Biscay, and with common dolphins only in the Bay of Biscay.

The range of surface water temperatures at which fin whale sightings occurred, range between 16.5° C and 23.0° C, with 20° C being the most frequent temperature in the Bay of Biscay and 17° C in the Atlantic area, while, for common dolphin, these ranged from 17.0°-22.5° C, with 19.5° C being the most frequent.

REFERENCES

Aguilar, A., Grau, E., Sanpera, C., Jover, L. and Donovan, G. 1983. Report of the 'Ballena ' whale marking and sighting cruise in the waters of western Spain. Rep. Int. Whal. Commn, 33: 649-655.

Buckland, S.T. and Anganuzzi, A.A. 1988. Estimated trends in abundance of dolphins associated with tuna in the eastern tropical Pacific. Rep. Int. Whal. Commn, 39: 411-437.

Buckland, S.T., Cattanach, K.L. and Lens, S. 1990. Fin whale abundance in the eastern North Atlantic, estimated from Spanish NASS-89 data. Rep. Int. Whal. Commn Doc. SC/43/Ba2.

Burnham, K.P., Anderson, K.P. and Laake, J.L. 1980. Estimation of density from line transect sampling of biological populations. Wildlife Monograph, 72.

Garcia-Castrillo, G. and Güemes, P.J. 1991. The marine mammals sighted during 'Cetacea-90'. Int. Cons. Expl. Mer (ICES). Doc. C.M. 1991/N:17.

Garcia-Castrillo, G. and Güemes, P.J. 1992. The marine mammals sighted during 'Cetacea-91' Int. Cons. Expl. Mer. (ICES). Doc. C.M.1992/N:14.

Güemes, P.J. and Garcia-Castrillo, G. 1992. Frequency of fin whale *(Balaenoptera physalus)* sightings in Biscay Bay. Int. Whal. Commn Doc. SC/44/NAB6.

Lens, S. 1991. North Atlantic Sighting Survey 1989: report of the Spanish cruise. Rep. Int. Whal. Commn, 41: 539-43.

Sanpera, C., Aguilar, A., Grau, E., Jover, L. and Mizroch, S.A. 1984. Report of the 'Ballena 2' whale marking and sighting cruise in the Atlantic waters off Spain. Rep. Int. Whal. Commn, 34: 663-666.

Table 1 Schools and individual sightings of Mysticeti

MYSTICETES	SCHOOLS	INDIVS.	INDIVS./SCHOOL
Balaenoptera physalus	46	76	1.6
Balaenoptera sp.	2	2	1.0
Total	48	78	1.6

Table 2 Schools and individual sightings of large Odontoceti

LARGE ODONTOCETES	SCHOOLS	INDIVS.	INDIVS./SCHOOL
Globicephala melas	3	21	7.0
Orcinus orca	1	1	1.0
Large odontocetes	3	15	5.0
Total	7	37	4.3

Table 3 Schools and individual sightings of small Odontoceti

SMALL ODONTOCETES	SCHOOLS	INDIVS.	INDIVS./SCHOOL
Delphinus delphis	15	262	17.4
Stenella coeruleoalba	3	220	73.3
Tursiops truncatus	1	10	10.0
Phocoena phocoena	2	4	2.0
Dolphin sp.	11	128	11.6
Total	32	624	22.8

Table 4 Fin whale (*Balaenoptera physalus*) encounter rates by distance and by square

REGION	ENCOUNTER RATE schools/100 nautical miles	ENCOUNTER RATE schools/square
Atlantic area	1.75	4.42 (SD 0.16)
Bay of Biscay	0.59	1.38 (SD 0.10)
Total	0.99	2.33 (SD 0.12)

Table 5 Common dolphin (*Delphinus delphis*) encounter rates by distance and by square

REGION	ENCOUNTER RATE	ENCOUNTER RATE
Atlantic area	0.17	0.37 (SD 0.03)
Bay of Biscay	0.39	0.51 (SD 0.05)
Total	0.31	0.47 (SD 0.04)

Table 6 Co-presence of fin whales (*Balaenoptera physalus*) with other animal species

% CO-PRESENCE	ATLANTIC AREA	BAY OF BISCAY	TOTAL
Calonectris diomedea	13	0	13
Sterna sp.	0	0	0
Sula bassana	0	2	2
Larus sp.	0	2	2
Tuna	2	2	4

Table 7 Co-presence of common dolphins (*Delphinus delphis*) with other animal species

% CO-PRESENCE	ATLANTIC AREA	BAY OF BISCAY	TOTAL
Calonectris diomedea	13	0	13
Sterna sp.	0	6	6
Sula bassana	0	13	13
Larus sp.	0	0	0
Tuna	0	6	6

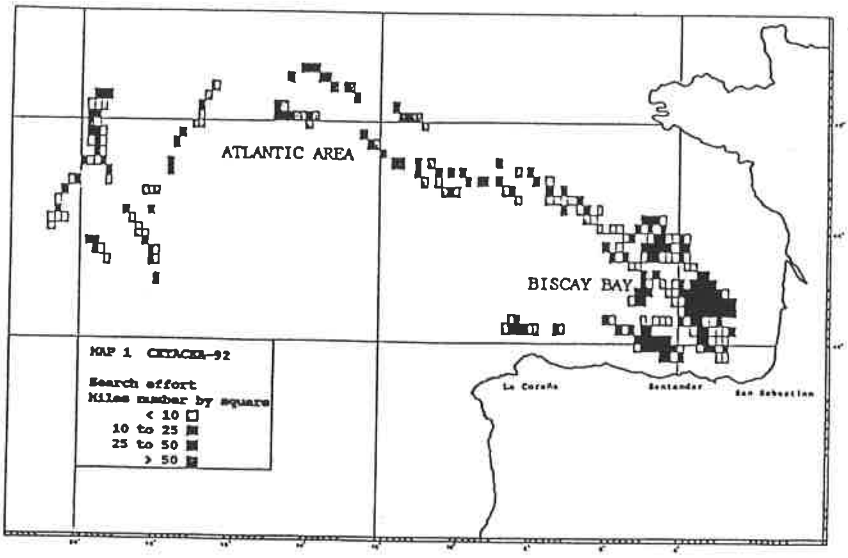

Fig. 1 Area covered by the survey and cruise tracks

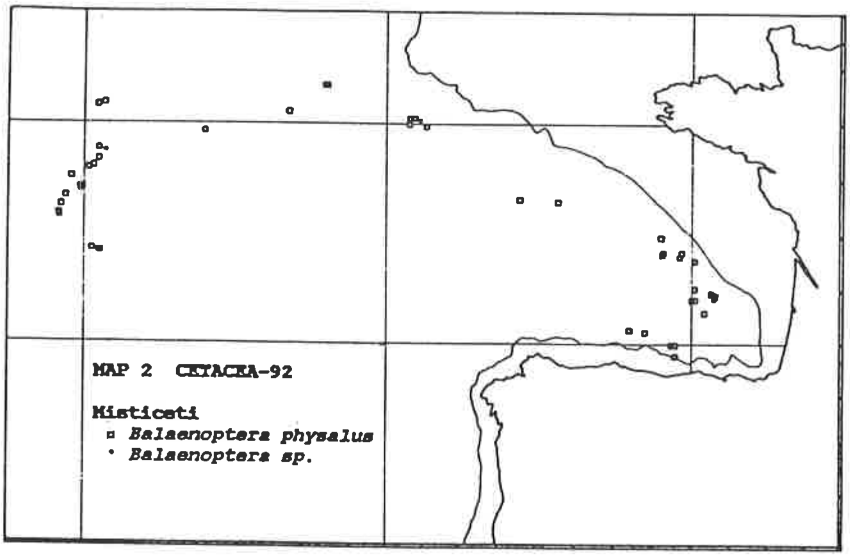

Fig. 2 Distribution of fin whale sightings

DISTRIBUTION AND ABUNDANCE OF FIN WHALES IN THE WESTERN MEDITERRANEAN DURING THE SUMMER

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The fin whale (*Balaenoptera physalus*) is the most common large cetacean inhabiting the Mediterranean Sea. The population congregates during the summer in the northwestern fringe of the basin and migrates to the southern latitudes in the Mediterranean for reproduction in the winter. However, the identity of the stock remains unclear. In order to obtain more information on the occurrence and abundance of fin whales in the Mediterranean, a sightings survey was conducted during August 1991, with two main aims: firstly, to describe the distribution of the species; secondly, to estimate the size of the population of fin whales in the western Mediterranean basin during the summer feeding season.

METHODS The survey covered 593,658km^2 of the western Mediterranean basin, between the straits of Gibraltar and Corsica and Sardinia. The area was stratified into five sub-areas to carry out separate analyses if required. A cruise track was designed to provide a representative sample of data for each area. The tracks were organised in a systematic zigzag pattern for efficiency, with starting points determined randomly (Figure 1 shows the areas and cruise tracks).

The survey was conducted from the Greenpeace boat SIRIUS, with a cruising speed of ten knots. The survey was conducted in closing mode, i.e. all schools sighted were approached to confirm species idenfitication and to estimate school size.

Line transect sampling methods (Burnham *et al.*, 1981) were used for the analysis of the data and to calculate the estimates of abundance. The data analysis was undertaken using the computer program DISTANCE (Laake *et al.*, 1991).

DISTRIBUTION The total number of fin whale schools sighted was 62 (Fig. 2), of which 59 were primary sightings. Fin whales were sighted only in the Liguro-Provençal basin, between the Gulf of Lions and the western Ligurian Sea, north of the Balaeric Islands. No whales were seen in any other area. Whales were found in deep cool waters, rich in euphausiids on which they feed. The mean water depth at which sightings were made was 2,285m.

Whales were found in groups of one or two individuals, with a mean group size of 1.3. No mother-calf pairs or yearlings were observed.

ABUNDANCE Analysis was carried out using data from the two northern sub-areas. The effort was stratified according to sea state. The optimal conditions were considered those with a Beaufort value between 0 and 3. In these conditions, a total of 981.1 nautical miles were searched, with 59 primary sightings of fin whales.

The number of whales was estimated at 4,291 with a standard error of 1,450, a CV of 32.7%, and a 95% confidence interval of 2,182-8,440 whales.

CONCLUSIONS Fin whales concentrate, during the summer, in the cool productive waters of the northern basin of the Western Mediterranean, where they can find appropriate food resources.

No calves or yearlings were seen, although they have been reported in the area in previous years.

The population estimate of 4,291 fin whales is an absolute estimate for the western Mediterranean during the summer. This number of whales highlights the importance of the northwestern Mediterranean as an essential habitat for the feeding rquirements of fin whales.

ACKNOWLEDGEMENTS Thanks are due to all those who participated in the cruise, especially to the crew of M/V SIRIUS. Participation of University of Barcelona personnel was funded by ICONA and CICYT, (projects NAT90-1255-E and NAT91-1128-CO4-02). Collaboration with PSH was made possible by British Council Integrated Actions grant no. 290A.

REFERENCES

Burnham, K.P., Anderson, D.R. and Laake, J.L. 1980. Estimation of density from line transect sampling of Biological populations. Wildlife Monographs, 72: 1-102.

Laake, J.L., Buckland, S.T., Anderson, D.R. and Burnham, K.P. 1991. DISTANCE user's guide. Unpublished mimeo, 53pp.

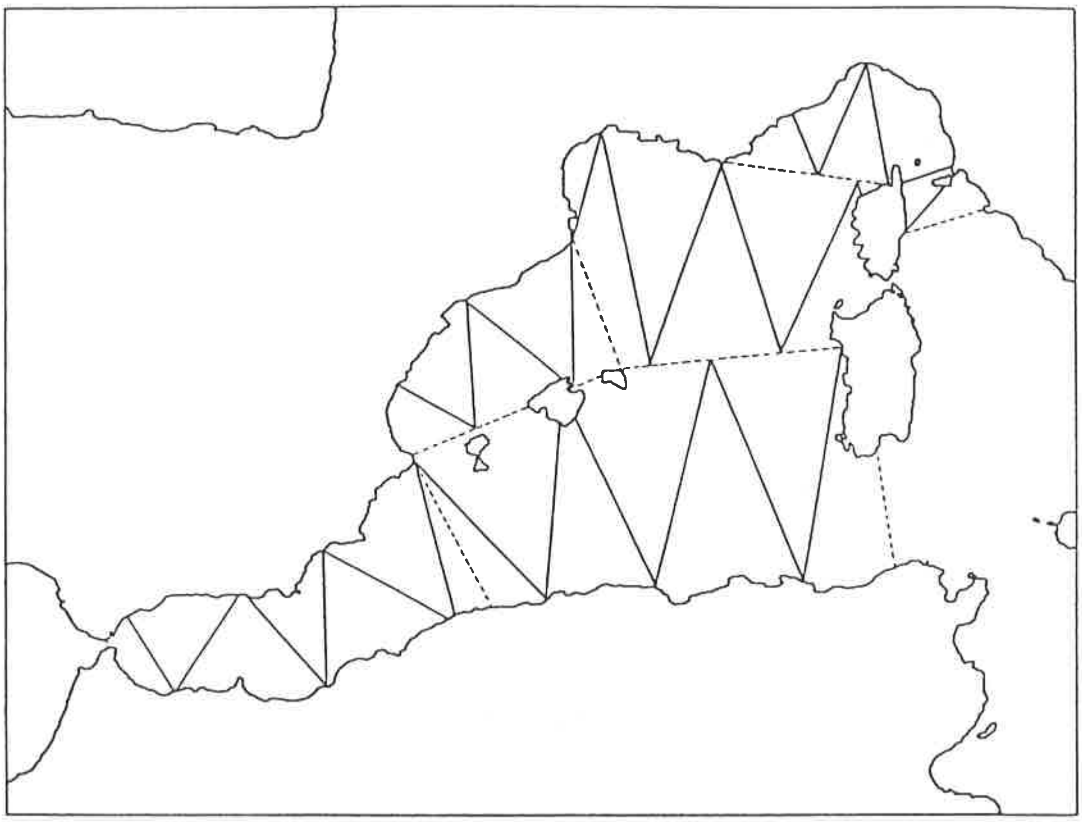

Fig. 1 Area covered by the survey and cruise tracks

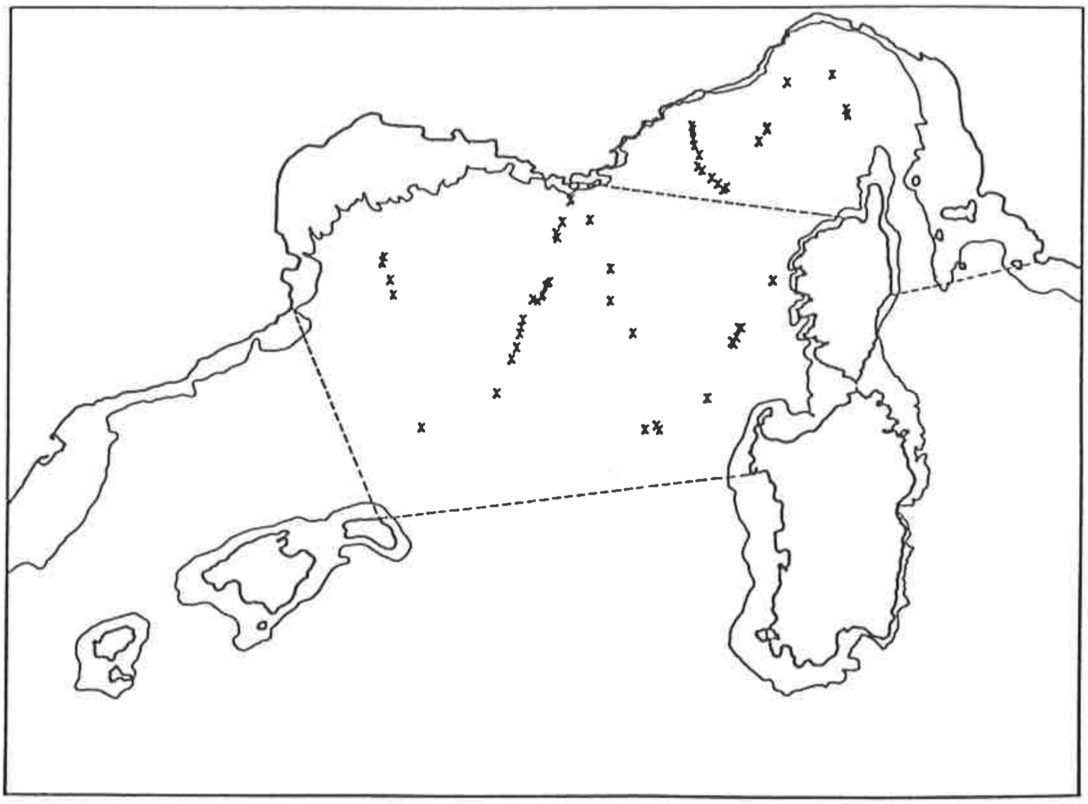

Fig. 2 Distribution of fin whale sightings

THE WINTER PRESENCE OF THE FIN WHALE IN THE LIGURO-PROVENÇAL BASIN: PRELIMINARY STUDY

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INTRODUCTION The fin whale (*Balaenoptera physalus*) is well known to be abundant in the Liguro-Provençal basin during summer time, its population being estimated somewhere between 1,500 and 8,000 animals from sightings surveys performed by different teams working there regularly. The seasonal status of the species has been relatively controversial: in the 1970's a common opinion was that animals were almost absent in winter, but recently, knowledge and opinion about this matter continue to change. The problem is considered here from the viewpoint of sightings per unit of searching effort. From five years of field data in the region, we extracted all the segments cruised during winds of below Beaufort 3, between the end of October and April, and from these obtained "winter" encounter rates, which we compared to the results of summer surveys, arising from data processed by the line transect method.

Previous Results Viale (1977) proposed the idea of a double migration occurring yearly: the summer population, which she estimated at around 2,000 individuals for the north of the western Mediterranean Sea, would come from wintering grounds in the tropical Atlantic, and a distinct stock would migrate from the north Atlantic to winter and calve in the Liguro-Provençal basin. Such a scheme has never gained field evidence, and would also be largely uneconomic for the animals from an energetic point of view. Duguy and Vallon (1977) carried out an analysis from ferryline sightings and concluded that the summer concentration in the basin decreases from September and October, the fin whales moving progressively southwest; but they admitted this apparent tendency could also result from a simultaneous decrease of sighting effort beween Provençe and Corsica. They also noted the regular sightings of fin whales around Corsica and the strandings of calves occurring in winter, and argued that a concentration in the north-east of the western basin progressively takes place during spring; these authors did not discard the possibility of a migration through Gibraltar strait. Di Natale and Mangano (1982) noted the regular presence of the species in the Tyrrhenian Sea, including in spring and autumn. More recently, Duguy (1991) reported that part of the population remains in the Liguro-Provençal basin during winter, and Gannier and Gannier (1990, 1992) bring new field evidence to support that opinion. Hashmi and Adloff (1991) after more than 11,000 km cruised in Gibraltar strait during spring, summer and autumn, report only five sightings of fin whales. Zanardelli *et al.* (1992) after two successive summer surveys, argue that fin whales appear in the Ligurian Sea in June, and progressively leave the sector from September to unknown breeding grounds. Viale (pers. comm., 1992) performed a six-week satellite-tracking experiment on a fin whale during autumn and found that the animal remained in the Provençal basin.

Almost all the above reports about the winter status of the fin whale in the region suffer from either no information on sighting effort, or the absence of effort in winter. Marini *et al.* (1992) draw an interesting picture from regular ferry trips in the Tyrrhenian Sea. They calculate a sighting per cruise index, corrected for sea state, and find an index of about 0.4 whale per cruise in winter against about one whale per cruise in spring and summer. Although not statistically tested, these figures show the winter presence of the fin whale and its seasonal variation.

SURVEY AREA AND SAMPLING METHOD The geographical area is the Liguro-Provençal basin of the Western Mediterranean Sea, north of 41° N and east of 6°30', E (Fig.1). The survey platform is a 30 ft sailing ship, with a cruising speed of 5 knots. Sampling has taken place all year round in open sea, with a cruise duration of between 24 and 72 hours, depending on the sighting conditions. All species of cetaceans are noted, the fin whale and striped dolphin being the main subjects for quantitative study. No survey grid is pre-designed: regions of interest are visited in turn, depending upon the weather conditions. A sample segment is 20 to 60 miles long in daylight hours with less than 12 knots of wind; other track-lines are excluded from the quantitative analysis. Each summer has provided about 1,000 miles of sampling, while the surveys cruised from mid-autumn to early spring since 1988, have resulted in 800 miles of sample segments.

RESULTS AND DISCUSSION The "winter" surveys are summarised in table 1; they result in a corresponding encounter rate of 0.0176 pod per mile or 0.0257 whale per mile of sampling. The CV has been calculated at around 1.2, which is a fairly high value. These results are compared to those obtained in summer, using "Distance" software of line transect modeling: the data processing yielded densities of 0.036 and 0.040 whale per km^2, for the summers of 1991 and 1992 respectively. In order to compare the summer results with the average "winter" result, we have pooled the data sets from the summers 1991 and 1992, and obtained the figure of 0.0355 whale per km^2 (CV=18.6%), with the associated encounter rate of 0.062 pod per mile (see table 2). Thus the ratio of encounter rates between summer and winter is about 3.5:1. This difference is significant at the 95% confidence level, thus indicating that the densities of whales in the Liguro-Provençal basin should be significantly lower in winter than in summer. A closer look at the winter surveys shows that visibility conditions were generally closer to the limit of tolerance because sun glare was more intense and wind speed often higher than 8 knots; furthermore, sample lengths were often shorter for various reasons. These factors might contribute to a slight under-estimation of the winter index.

DISCUSSION AND CONCLUSIONS This winter field research is unique in the region. The results derived from these surveys provide the first opportunity to assess the seasonal status of the fin whale in the Liguro-Provençal basin. It is clear that fin whale density decreases in winter, reaching a possible minimum in December and January. It is probable that whales are spread over a much larger area in the Mediterranean Sea during winter, and then concentrate on rich feeding grounds from the late spring to early autumn. Indeed, from February onwards, the number of animals seem to increase, and this is probably connected with the onset of the reproduction period of the krill *Meganyctiphanes* in the area. More sampling is still needed to increase the reliability of this work, particularly with respect to the late spring period, when the concentration is supposed to build up.

REFERENCES

Viale, D. 1977. *Ecologie des cétacés de la Méditerranée Occidentale.* Thèse d'état, Université de Paris 6.

Duguy, R. and Vallon, D. 1977. Le Rorqual commun en Méditerranée occidentale: état actuel des observations. Rapp. Comm. int. Mer Médit., 24(5): 21-24.

Di Natale, A. and Mangano, A. 1983. Presence and distribuion of *Balaenoptera physalus* and *Balaenoptera* spp. in the central Mediterranean Sea. Rapp. Comm. int. Mer. Médit., 28(5): 185-187.

Duguy, R. 1991. Les mammifères marins de la Méditerranée occidentale. Bulletin de la Société Zoologique de France, 114(3): 89-96.

Gannier, A. and O., 1991. Cetacean sightings in the Mediterranean Sea: second report. P. 39. In *European Research on Cetaceans - 5* (Ed. P.G.H. Evans) Proc. 5th Ann. Conf. ECS, Sandefjord, Norway, 21-23 February 1991. European Cetacean Society, Cambridge, 131pp.

Hashmi, O. and Adloff, B. 1991, Surface frequency of cetaceans in the strait of Gibraltar. Pp. 16-17 In *European Research on Cetaceans - 5* (Ed. P.G.H. Evans) Proc. 5th Ann. Conf. ECS, Sandefjord, Norway, 21-23 February 1991. European Cetacean Society, Cambridge. 131 pp.

Marini, L., Consiglio, C., Angradi, A. M., Finoia, M. G. and Sanna, A. 1992. *Cetacei nel Mar Tirreno, Risultati della campagna d'Avvistamento 1989-1991*. Rome 107 pp.

Zanardelli, M., Notarbartolo di Sciara, G. and Jahoda, M. Photo-identification and behavioural observations of fin whales summering in the Ligurian Sea. Pp. 86-89. In *European Research on Cetaceans - 6* (Ed. P.G.H. Evans) Proc. 6th Ann. Conf. ECS, San Remo, Italy, 20-22 February 1992. European Cetacean Society, Cambridge. 254 pp.

Table 1 Fin whale (*Balaenoptera physalus*) Encounter Rates

MONTH & YEAR		SAMPLE LENGTH IN MILES	NO. OF SIGHTINGS
Oct/Nov	1988	40	1
Oct/Nov	1989	160	2
Feb	1990	160	4
March	1991	25	0
Dec	1991	125	0
Jan	1992	75	0
March	1992	55	2
April	1992	75	5
Dec	1992	40	0
Jan	1993	40	0

Table 2 Abundance estimates for fin whales using "Distance" analysis

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             Point         Standard      Percent Coef.        95 Percent
Parameter    Estimate       Error        of Variation     Confidence Interval
---------  -----------   -----------   --------------   ----------------------
  f(0)      .1812E-02     .1945E-03        10.7         .1465E-02    .2241E-02
  p         .3679         .3950E-01        10.7         .2975        .4550
  ESW       551.9         59.25            10.7         446.3        682.5
  n/L       .6184E-01     .6670E-02        10.8         .4974E-01    .7688E-01
  DS        .3025E-01     .4603E-02        15.2         .2249E-01    .4069E-01
  SBAR      1.174         .1264            10.8         .9483        1.452
  D         .3550E-01     .6619E-02        18.6         .2471E-01    .5100E-01
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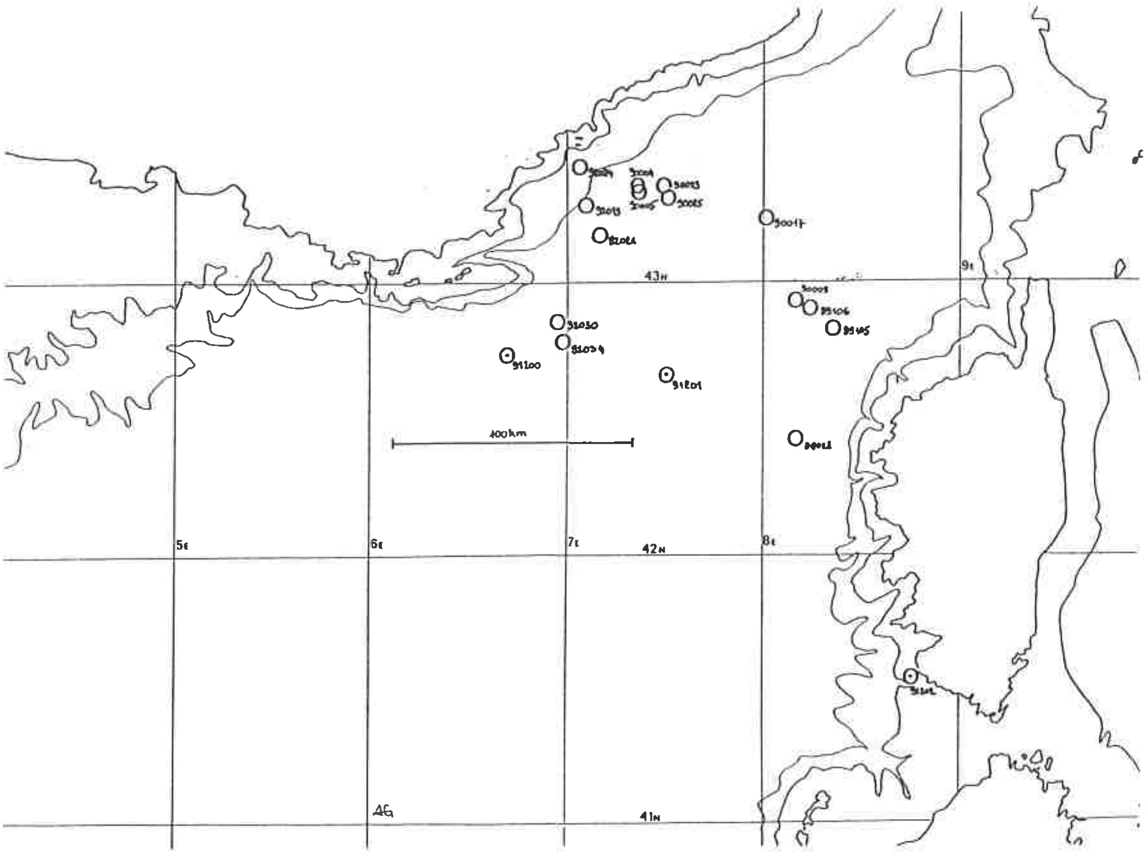

Fig. 1 Survey area and winter sightings

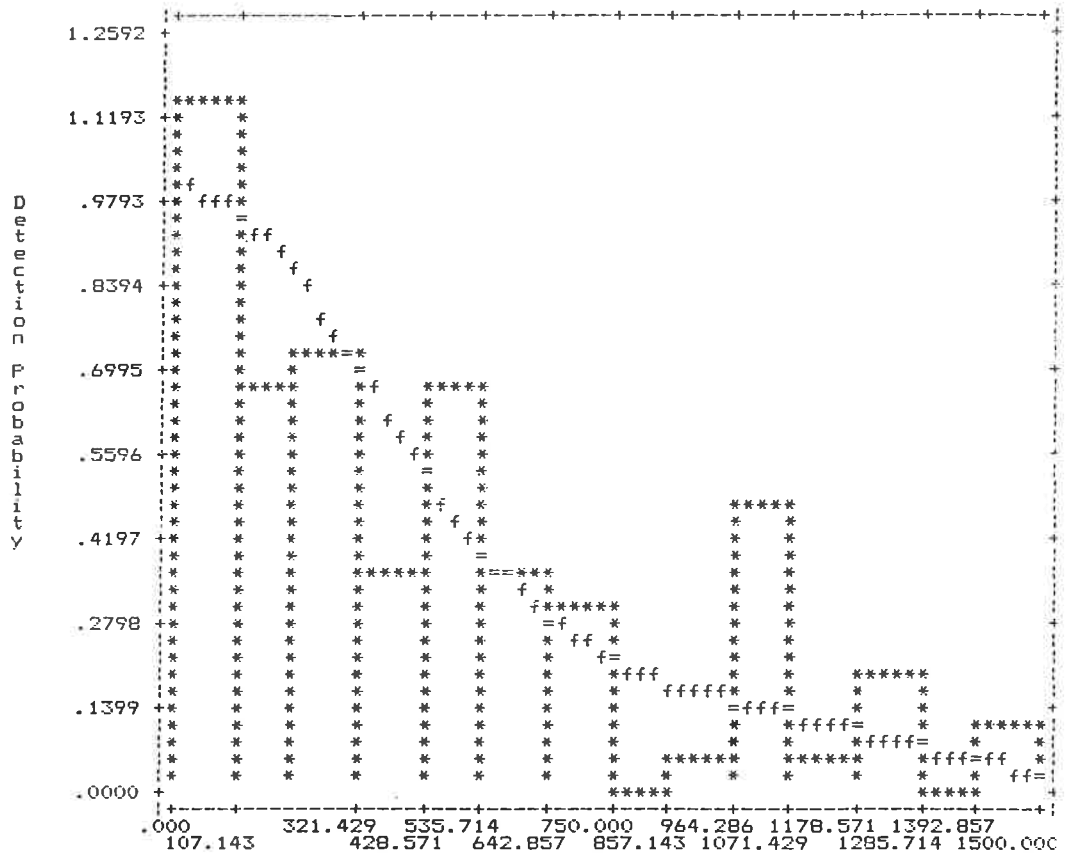

Fig. 2 Detection probabilities for fin whale sightings from "Distance" analysis

POPULATION ESTIMATES OF FIN WHALES AND STRIPED DOLPHINS SUMMERING IN THE CORSO-LIGURIAN BASIN

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INTRODUCTION During recent years, several studies have highlighted the importance of the Corso-Ligurian basin as one of the offshore areas of the Mediterranean Sea where cetaceans are most abundant (Forcada *et al.*, in press; Notarbotolo di Sciara *et al.*, in press), and emphasised the need for the establishment of a marine sanctuary to conserve the integrity of its fauna (Orsi Relini *et al.*, 1992; Notarbotolo di Sciara *et al.*, in press). To provide the background information needed for the proposal of appropriate conservation measures, and specifically to describe distribution and estimate both densities and absolute abundance of the principal cetacean species found in the Corso-Ligurian Basin, a survey cruise was organised in that region during August 1992 aboard the Greenpeace M/V SIRIUS. This was a co-operative project involving the Tethys Research Institute, the Greenpeace Mediterranean Sea Project, and the Department of Animal Biology of the University of Barcelona.

METHODS The survey covered an area of 58,646km^2, comprising the seas between western Corsica and the continental coast of France and Italy (Fig. 1), and encompassing the area which was proposed for the creation of a cetacean pelagic survey (Notarbartolo di Sciara *et al.*, in press). The data were stratified by wind speed; only observations made with a wind speed less than Beaufort 4, were considered. The survey was carried out during 6-9, 17, 19, and 20 August, 1992; the total search effort in the above stated conditions was 617.55 km.

The survey was designed to conform to the methods used in a previous survey by Forcada *et al.* (in press). Track-lines were plotted using a saw-tooth pattern, the starting point being determined randomly. The vessel used for the survey, the Greenpeace 46m-long M/V SIRIUS, cruised at a constant speed of 18.5kmh^{-1}(10 knots). Observations from dawn to dusk were made from a platform situated 8m above sea level, by a minimum of four observers on duty in three-hour shifts.

Upon sighting a cetacean group, the following data were logged: angle formed by the direction of the sighting and the direction of the vessel; estimated distance of the group at the time of sighting; and position (determined by satellite Global Positioning System). In most cases, the cetacean group was approached to identify the species and estimate its group size; searching was then resumed as soon as possible.

To calculate densities and abundance of cetaceans, data collection and analysis were performed according to the line transect sampling method (Burnham *et al.*, 1980). For the analysis, the computer program *Distance* (Laake *et al.*, 1991), was used. Calculations of effort and of the size of the area were made, using software which had been specifically designed for previous survey cruises by Forcada *et al.* (in press).

RESULTS Cetaceans were observed 129 times. Most sightings were of striped dolphins (*Stenella coeruleoalba*) (52% of the sightings) and fin whales (*Balaenoptera physalus*) (41%). Risso's dolphins (*Grampus griseus*), common dolphins (*Delphinus delphis*), and long-finned pilot whales (*Globicephala melas*) accounted for the remaining 7% of the sightings. The distribution of sightings of fin whales & striped dolphins is shown in Figure 2.

Mean school sizes, densities and population estimates could only be calculated for striped dolphins and fin whales, data for other species being insufficient. The analysis of the data was based on primary sightings (67 groups of striped dolphins and 48 groups of fin whales). A summary of the results is given in Table 1.

CONCLUSIONS Population sizes were estimated at around 25,330 individuals for striped dolphins (lower 95% confidence interval = 12,280, upper 95% confidence interval = 52,220), and around 1,012 individuals for fin whales (lower 95% confidence interval = 611, upper 95% confidence interval = 1,675).

A repeat of the survey is recommended at different times of the year, in order to detect possible migratory habits of the species under study, particularly of fin whales.

The results of this study confirm the importance of the cetacean faunal assemblages in the area, and stress the need for the adoption of conservation measures.

ACKNOWLEDGEMENTS We gratefully acknowledge the support of Xavier Pastor, Coordinator of the Greenpeace Mediterranean Sea Project, who made this cruise possible by dedicating the M/V SIRIUS to the survey, and to the entire crew of the SIRIUS for their co-operation during the cruise. Our thanks also go to Alex Aguilar and Phil Hammond for their priceless advice and assistance. This research could not have been completed successfully without the help of a team of dedicated observers: Agnès Carlier, Gabriella Guerra, Giancarlo Lauriano, Laura Silvani, Lucia Simion, Gianni Squitieri, Paolo Biocca, and Tiziana Valentini. Mr. P. Gavagnin, Director of Portosole, offered valuable assistance when the ship docked in San Remo.

REFERENCES

Burnham, K.P., Anderson, D.R. and Laake, J.L. 1980. Estimation of density form line transect sampling of biological populations. Wildlife Monogr., 72:1-202.

Forcada, J., Aguilar, A., Hammond, P., Pastor, X. and Aguilar, R. 1992. Striped dolphin abundance in the Western Mediterranean Basin after the 1990 epizootic. Pp. 105-107. In *European Research on Cetaceans* -6 (Editor P.G.H.Evans). Proc. 6th Ann. Conf. ECS, San Remo, Italy, 20-22 February, 1992. European Cetacean Society, Cambridge. 254 pp.

Laake, J.L., Buckland, S.T., Anderson, D.R. and Burnham, K.P. 1991. Distance User's Guide. Unpublished mimeo. 53 pp.

Notarbartolo di Sciara, G., Ausenda, F., Relini, G. and Orso-Relini, L. (In press). Project Pelagos: proposal of a pelagic Biosphere Reserve in the Ligurian-Corsican-Provençal Basin (Mediterranean Sea). International Conference on Ocean Management in Global Change. Large Marine Ecosystems: a new approach to ocean management. Genova, 24 June 1992.

Notarbartolo di Sciara, G., Venturino, M.C., Zanardelli,, M., Bearzi, G., Borsani, J.F. and Cavalloni, B. (In press). Cetaceans in the Central Mediterranean Sea: distribution and sighting frequencies. Boll. Zool.

Table 1 Summary of the survey's results

Balaenoptera physalus (N = 48)				
	$\bar{X}$	CV	SE	95% conf. int.
mean group size	1.583	7.7	0.1222	1.356 - 1.849
group encounter rate/km	0.0777	19.5	0.0151	0.0473 - 0.1276
density of groups (n/km^2)	0.0109	20.1	0.0022	0.0065 - 0.0182
individual density (n/km^2)	0.0173	21.6	0.0037	0.0104 - 0.0286
total number of animals	1012	21.6	218.2	611 - 1675

Stenella coeruleoalba (N = 67)				
	$\bar{X}$	CV	SE	95% conf. int.
mean group size	22.45	14.8	3.325	16.73 - 30.12
group encounter rate/km	0.1085	28.1	0.0305	0.0534 - 0.2204
density of groups (n/km^2)	0.0192	29.3	0.0056	0.0092 - 0.0402
individual density (n/km^2)	0.4318	32.8	0.1417	0.2095 - 0.8904
total number of animals	25330	32.8	8313	12280 - 52220

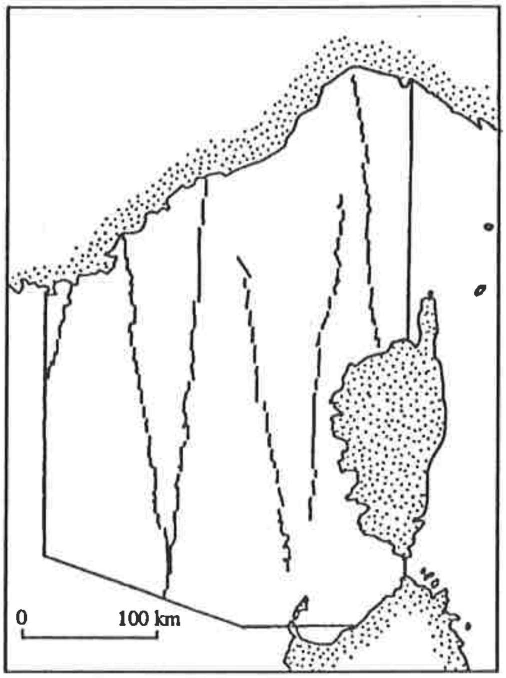

Fig. 1 The study area and cruise tracks plotted with GPS

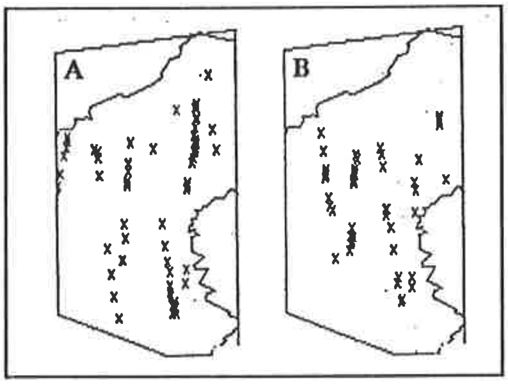

Fig. 2 Distribution of sightings of (A) striped dolphins and (B) fin whales

STRIPED DOLPHIN ABUNDANCE ESTIMATE IN THE LIGURO-PROVENÇAL BASIN

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INTRODUCTION The striped dolphin (*Stenella coeruleoalba*) is the most numerous species in the Western Mediterranean Sea. Until 1991, when a transect study was run by Greenpeace and the University of Barcelona, the question of its population had been poorly addressed. Among different geographical subsectors, the liguro-provençal basin appears to be one of the more densely populated in the Mediterranean Sea. The aim of our study was to give an abundance estimate for that region. For this purpose, we processed the data collected during summer 1992, using the "Distance" line transect software. Another point of interest was the seasonal status of the species, which has rarely been properly addressed. Thanks to regular sighting effort in the Liguro-Provençal basin from late autumn to mid spring, we had accumulated sufficient data to compare seasonal abundance using encounter rates.

SURVEY AREA AND SAMPLING METHOD The Liguro-Provençal basin lies in the northeast of the Western Mediterranean Sea. Oceanographers have shown this sector to be comparatively rich, and it is one of the areas most densely populated by cetaceans. We report here on the region included between the continental slope, 41°00' N, and 06°00' E (see Figure 1).

The platform was our 30 ft sailing ship, used since 1988 for field study, with a cruising speed of about 5 knots. The observation height was three metres above sea level, and cetaceans were detected by naked eye and then identified with binoculars; the front sector surveyed varied from 120° to 180°. During each summer, the total effective effort was around 30 days in open sea, depending on the weather conditions; for other seasons, the effort was much more variable amounting to 25 days per year. From the total effort, we extracted the segments covered in the area during the summers of 1991 and 1992, daylight hours, with winds less than Beaufort 3, to obtain a value for corrected effort. To compare the summer results with those of the rest of the year, we needed to retain all the segments cruised since 1989, for the October-May period.

For each summer survey, the sampling was performed randomly within the area of survey. No survey grid was used and regions were visited in turn depending on the meteorological conditions and practical possibilities. Thus, coverage may be heterogeneous at the end of each survey. Each sample was 20 to 60 miles long, generally using the closing mode, because the recording of sighting parameters required schools to be approached.

The angle of sighting was measured with a personal compass and the distance estimated and, if exceeding 400 m, recorded on a telephoto lens picture for later measurement. The size of the school was estimated using minimum (counted), maximum and "best" values.

RESULTS The sightings from the summer surveys in 1991 and 1992, were processed with "Distance" software. These data sets have been stratified into two areas: "Provençe" and "Gênes Corse". The stratification was necessary for the following reason: during the summer of 1992, the coverage was higher in "Provençe" than in any other areas. Corrected effort amounted to 657 miles in 1991, and 848 miles in 1992.

For the analysis, the perpendicular distances were truncated to 800m because of the low sample sizes beyond that distance. The software calculates the overall density from the result for each stratum with the area covered, for each summer. By doing so, we obtain densities of 0.84 dolphin per km^2 in 1991, and 1.03 dolphin per km^2 in 1992, the corresponding CV being 23.2% and 23.9% respectively. A t-test showed that densities were significantly different from eachother. Nevertheless, it is possible to pool both years in order to obtain an estimate of the "average density for the summer of 1991 and 1992", again with two strata. This results in a density estimate of 0.945 dolphins per km^2 (CV = 20.6%), with a 95% confidence interval between 0.70 and 1.30 dolphins per km^2. Since the area of the sector sampled is estimated to be 20,000 km^2, the estimate of the summer population lies between 14,000 and 26,000 dolphins (see table 1).

For an assessment of seasonal variation of striped dolphin abundance in the Liguro-Provençal basin, a direct density estimate would suffice, but this was not yet possible. Thus we must rely on a comparison of the average encounter rates: for the summers of 1991 and 1992, this equals 0.093 school per mile (CV = 12.7%). The summer encounter rate was slightly, but significantly, higher than the winter one.

DISCUSSION If we compare our results with those of Forcada *et al.* (1992), the density of striped dolphins in the liguro provençal basin appears to be 2.5 times higher than the overall figure of 0.38 dolphins per km^2 given for the entire Western Mediterranean Sea. This confirms the Liguro-Provençal basin as an important area for the species. Moreover, during the Grenpeace survey of 1991, nearly two-thirds of the schools were sighted north of 41°N, within an area less than one-third of the total western basin, suggesting that both studies might provide comparable densities for the northern sector of the Western Mediterranean Sea.

We must bear in mind the fact that our survey was made at a speed of 5 knots compared with 8 knots for the "Greenpeace" survey; this lower speed could result in an over-estimate of encounter rate and density. From Hiby (1982), we derived an evaluation of this possible bias, assuming the schools of dolphins to be moving randomly and having a circular detection range. For a speed ratio of 5:3, we came to an over-estimation factor of 1.09 for number per distance travelled which could eventually be used to correct the calculated density downward.

The apparent increase of abundance between 1991 and 1992, results from the great variation in the mean school size, which increases from 12.4 dolphins per school in 1991 to 19.8 in 1992. Although the coefficents of variation are particularly high (more than 30% for the stratum "Gênes + Corse"), this significant increase in size requires some discussion. The social structure of the striped dolphin is not as clearcut as, for example, the bottle-nosed dolphin. The school size may vary in response to biological factors, such as abundance of food, and it is also known to increase during the breeding period. A mean school sizes variation could also result from variation in the timing of the calving period in relation to the survey. Another possible factor could be an increase in school size following the 1990-91 epizootic.

Assuming a broadly similar number of animals present in the area of survey, an increase in school size from one year to the next should be counterbalanced by a decrease in the number of schools of dolphins, and this should be detected in the data analysis. Indeed, for each stratum, we noted such a decrease (see table 1), and the density estimate of schools shifts from 0.0726 school per mile in 1991 to 0.0645 school per mile in 1992. The increase in abundance for these successive years might be a sign of a population recovery of striped dolphins in the region following the severe disease outbreak of 1990 and 1991.

Seasonal variations of the population are addressed here by comparison of encounter rates, for which sufficient data sets were available outside the summer season; The differences between the two periods were found to be small. This indicates that striped dolphins are resident in the Liguro-Provençal area. School abundance seems to remain broadly the same, Nevertheless, the mean school sizes may vary and local changes of occurrence may take place as a consequence of food availability. We must not forget that the total survey area is only about 100 miles long and 100 miles wide - a mere 30 hours journey for a school of dolphins travelling gently! An apparent absence in seasonal variation might also emerge from the data reported by Marini *et al.*, 1992, after a survey programme in the central Tyrrhenian Sea.

CONCLUSIONS AND RECOMMENDATIONS The abundance estimate presented here is of interest because the Liguro-Provençal was known to be an area of major importance for the striped dolphin in the Mediterranean Sea. This is firmly established by comparison of our results with the previous estimate given by Forcada *et al.* (1992) for the Western Mediterranean. Even if a slight, and predictable, over-estimation of the density may arise from the moderate speed of our platform, the line transect method has been applied successfully on our data samples, thanks to the "Distance" software provided by Steve Buckland of Scottish Agricultural Statistics Service. As a consequence, in the future, it should be possible to survey the striped dolphin population in the Liguro-Provençal basin with an inexpensive platform and a proven statistical method, and this may prove useful with the possible advent of an International Marine Sanctuary in that region. Our study clarifies the seasonal status of the striped dolphin, but additional results should improve this preliminary view.

REFERENCES

Forcada, J., Aguilar, A., Hammond, P., Xavier, P. and Aguilar, R. 1992. Population abundance of striped dolphins inhabiting the Western Mediterranean Sea. Pp. 105-107. In European Research on Cetaceans-6(ed. P.G.H. Evans). Proc. 6th Ann. Conf. ECS, San Remo, Italy, 20-22 Feb 1992. European Cetacean Society, Cambridge. 254 pp.

Hiby, L. 1982. The effect of random whale movement on density estimates obtained from whale sighting surveys, Rep. Int. Whal. Commn., 32: 791-793.

Marini, L., Consiglio, C., Angradi, A.M., Finola, M.G. and Sanna, A. 1992. *Cetacei nel Mar Tirreno Centrale, risultati della campagna d'avvistamento 1989-1991.* Rome. 107pp.

Table 1 Abundance estimate parameters from "Distance" software (CV are in brackets)

STRATUM, parameter	**YEAR** **1991**	 **1992**	 **1991+1992**
Provence: $10^2.f(0)$	0.330 (9.4)	0.286 (8.3)	0.297 (6.4)
Provence: D_s sch./km^2	0.0974(23.8)	0.0786(20.0)	0.0832 (6.4)
Provence: D dolp./km^2	0.902 (30.0)	1.375 (24.8)	1.260 (20.2)
Corse/Gênes: $10^2.f(0)$	0.332 (10.2)	0.218 (11.9)	0.260 (7.2)
Corse/Gênes: D_s sch./km^2	0.0575(25.0)	0.0381(29.0)	0.0452(18.6)
Corse/Gênes: D dolp./km^2	0.820 (29.8)	0.916 (33.6)	0.840 (29.2)
Both: D_s sch./km^2	0.0726	0.0645	0.0678
Both: D dolp./km^2	0.84 (23.2)	1.03 (23.9)	0.945 (20.6)

Table 2 Encounter rates for the period between late October and early May (n/L.10^3)

			YEAR		
MONTH	**1989**	**1990**	**1991**	**1992**	**1993**
October	136, 97				
November	37, 125				
December			54	125	
January			60	134	67
February		250,170 148, 50			
March			25	0, 80	
April		87, 40	0	80,100	
May	96, 85			63, 33, 67	

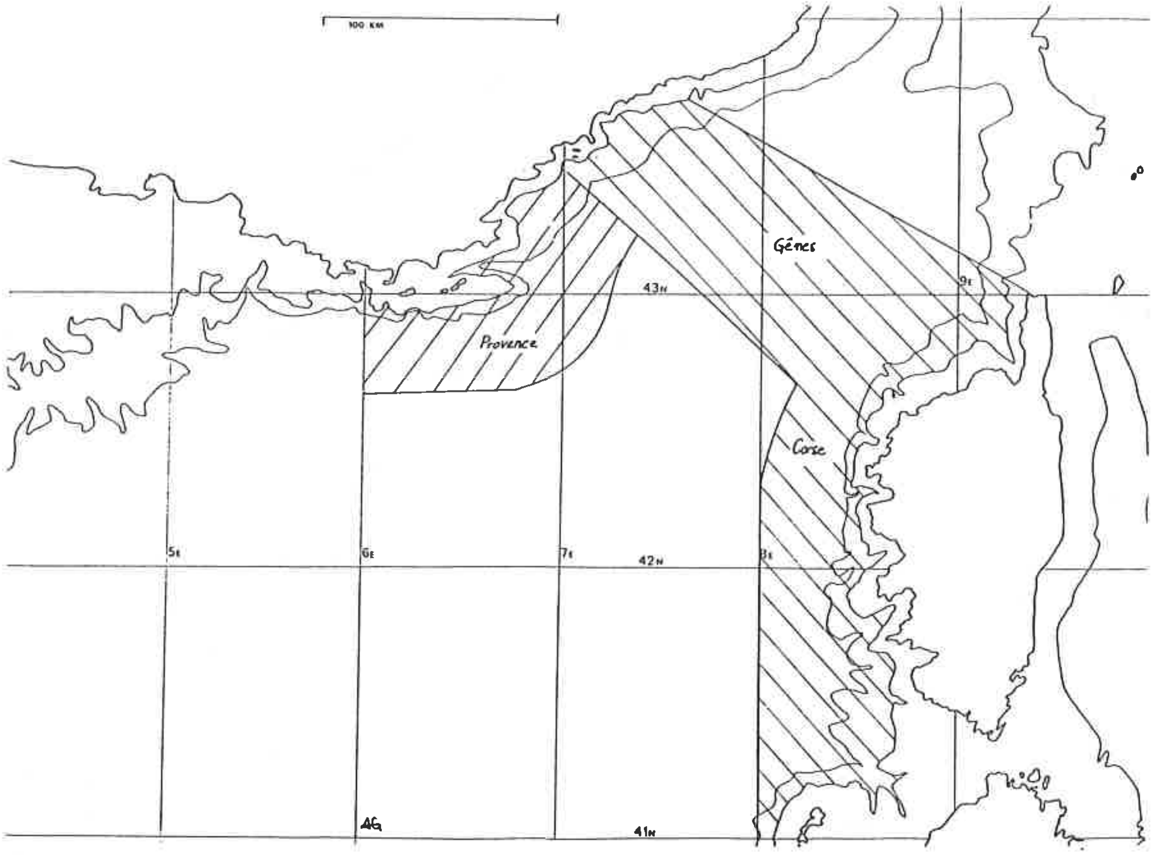

Fig 1. Area of survey and strata of sampling

DISTRIBUTION AND FREQUENCY OF CETACEANS IN THE LIGURIAN-PROVENÇAL BASIN AND IN THE NORTH TYRRHENIAN SEA (MEDITERRANEAN SEA)

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INTRODUCTION In summer 1992, research was conducted to record occurrence, distribution, sighting frequencies, and group size of cetaceans in the Ligurian-Provençal basin, in the north of Corsica, and around the Tuscan archipelago.

METHODS For the research, a 16 m. sailing vessel was used. The study was divided into seven cruises of 12 days each, during which with daily trips, about 1,300 nautical miles were covered, for a total of about 410 hours of observation.

At each sighting, a CIESM form was completed, in which we recorded density, position (calculated with GPS system), time of sighting, group size, presence of juveniles, and particular observations about their behaviour. We also documented encounters photographically to try to identify individuals from their natural markings, and for this reason, when it was possible we followed the groups with the vessel.

Most photographs were taken using a Pentax ME Super SLR camera with a 80-210mm, 35-70mm or 300mm lens. A variety of colour slide film was used, including Kodachrome 200, Ektachrome 100, 200 and 400. The best results were obtained using 200 ASA. Only photographs of good quality were selected for mounting and identification of individual animals.

During the period of the research, we have been supported by a staff of volunteers who have been trained by us with courses before the beginning of each cruise.

RESULTS Cetaceans were sighted on 64 occasions (Table 1), for a total of 537 individuals. The species observed with greatest frequency were striped dolphin (*Stenella coeruleoalba*), bottle-nosed dolphin (*Tursiops truncatus*), and fin whale (*Balaenoptera physalus*). In those cases when we were not able to identify species with certainty, we included them in the unidentified group. The difficulty in identifying some individuals was due to their behaviour, their surface swimming showing only the dorsal fin rather than flank markings, or remaining too far from the vessel.

Striped dolphins, common dolphins and fin whales were observed in deep, pelagic waters. Bottle-nosed dolphins were observed near the coast, particularly near the Island of Capraia, Macinaggio in Corsica, and the Isle of Elbe. Risso's dolphins were observed in areas of depth ranging from 700 to 1,800 m.

In the striped dolphin, we observed great variation in group size, typical of the social organisation of this species, even if the majority of groups comprised no more than five individuals, probably due to lack of food in the area under study (Table 1).

Common dolphins were always observed together with striped dolphins suggesting strong overlap in their ecological niches.

Sightings of fin whales involved isolated individuals in two cases, pairs in four cases, and three individuals in three cases (including a juvenile in one of the three cases). On three occasions, fin whales were seen with small dolphins. Fin whales were observed only in the Provençal basin.

Bottle-nosed dolphins were observed in most cases (60%) in groups of up to five individuals. Risso's dolphins were seen in relatively large groups, the three groups comprising 15-20 individuals.

During the entire period of the survey, juveniles of all species recorded, were sighted.

Table 1 Cetacean sightings by species

SPECIES	NO. SIGHTINGS	% SIGHTINGS	NO. INDIVS	% INDIVS
Stenella coeruleoalba	29	45.3	289	53.8
Tursiops truncatus	15	23.4	114	21.2
Delphinus delphis	3	4.7	42	7.8
Grampus griseus	3	4.7	55	10.2
Balaenoptera physalus	10	15.6	28	5.2
Not identified	4	6.3	9	1.7
TOTAL	64	100	537	99.9

Table 2 Frequency of striped dolphins

GROUP SIZE	N° SIGHTINGS	% SIGHTINGS
1 - 5	15	51.7
6 - 10	7	24.1
11 - 15	3	10.3
16 - 20	1	3.4
21 - 25	1	3.4
26 - 30	1	3.4
over 30	1	3.4
TOTAL	29	100.6

Table 3 Frequency of bottle-nosed dolphins

GROUP SIZE	N° SIGHTINGS	% SIGHTINGS
1 - 5	9	60.0
6 - 10	4	26.7
11 - 15	0	0
16 - 20	1	6.7
21 - 25	0	0
26 - 30	1	6.0
over 30	0	0
TOTAL	15	100.1

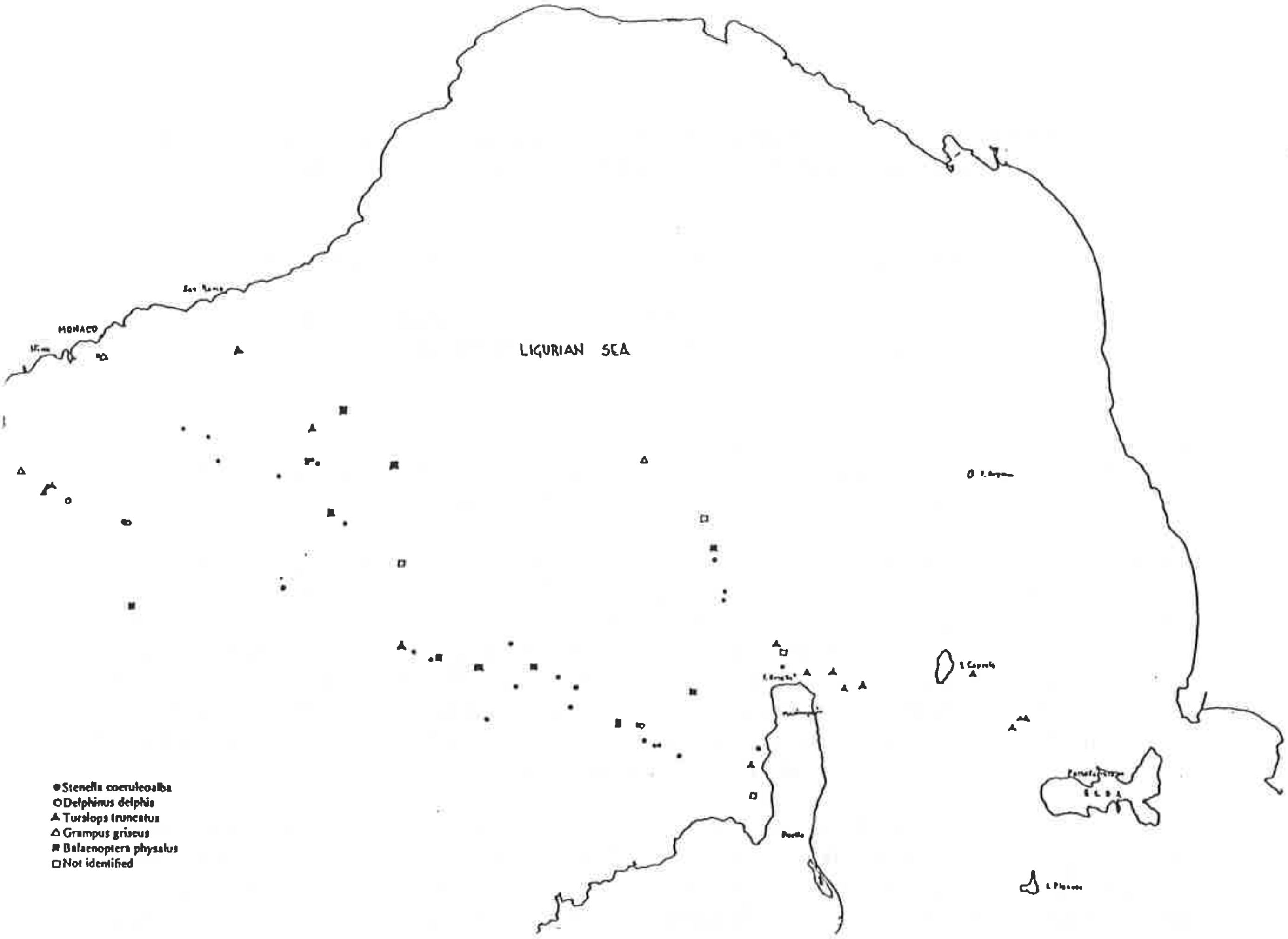

Fig. 1 Map of study area

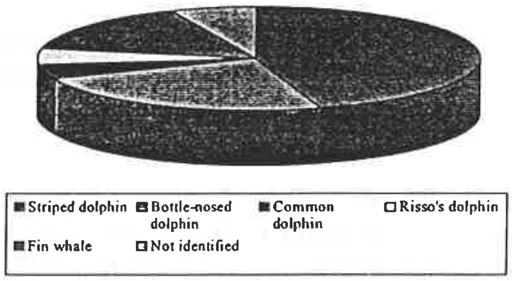

Fig. 2 Frequency of cetacean sightings by species

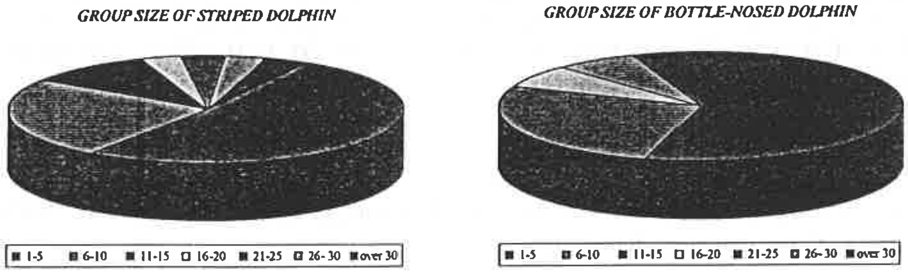

Fig. 3 Distribution of group sizes for striped and bottle-nosed dolphins

CETACEANS IN THE CENTRAL TYRRHENIAN SEA : THIRD (AND LAST?) YEAR OF SIGHTINGS : PRELIMINARY RESULTS

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Sighting cruises in the Central Tyrrhenian Sea have been carried out on board ferries between the Sardinian coast and continental Italy for the third consecutive year (Marini *et al.*, 1992). 79 trips were carried out every month from October, 1991 to September, 1992.

Tha data collected widely confirm the sightings made in previous years (Fig. 1). Particularly interesting was the seasonal presence of the genus *Balaenoptera* (30 sightings during 1992; in most cases fin whales, *B. physalus*), with a peak in April-May and minimum numbers between November and December (Fig. 2). Considering the previous observations made in the western part of the Mediterranean basin by ourselves (Marini *et al.*, 1992) and other authors (for example Gannier & Gannier, 1989, 1990; Hashmi & Adloff, 1991, for surveys in the Gibraltar area) a tentative hypothesis relating to the relative abundance and seasonal distribution of *Balaenoptera* sp. can be summarised in Figure 3.

As in previous years, breachings of fin whale (*Balaenoptera physalus*) were observed in January and August. Cuvier's beaked whale (*Ziphius cavirostris*) (6 sightings), bottle-nosed dolphins (*Tursiops truncatus*) (23 sightings) and Risso's dolphin (*Grampus griseus* (four sightings) were confirmed as relatively common, while sightings of sperm whale (*Physeter macrocephalus*) (three) and common dolphin (*Delphinus delphis*) (two) remained rare. Long-finned pilot whale (*Globicephala melas*) was not sighted this year. Striped dolphin (*Stenella coeruleoalba*) (108 sightings) was by far the most common species in the area throughout the year.

Since the sightings did not show substantial differences by comparison with those of previous years, the phase of data gathering is considered to be completed. However, it will be interesting to repeat sighting cruises after a number of years, in order to discover possible variations in the long term.

ACKNOWLEDGEMENTS We wish to thank all the people who have taken an active part in the sighting cruises, the National Railway Board and the Environmental Bureau of the Provincal Administration of Rome which sponsored the research.

REFERENCES

Gannier, A. and Gannier, O. 1989. Some sightings of cetaceans in the Western Mediterranean Sea. Pp. 62-64. In *European Research on Cetaceans - 3.* (Eds. P.G.H. Evans & C. Smeenk). Proc. 3rd Ann. Conf. ECS, La Rochelle, France, 24-26 Feb 1989. European Cetacean Society, Leiden, Netherlands. 132 pp.

Gannier, A. and Gannier, O. 1990. Cetacean sightings in the Mediterranean Sea: Second Report. P. 39. In *European Research on Cetaceans - 4.* (Eds. P.G.H. Evans, A. Aguilar & C. Smeenk) Proc. 4th Ann. Conf. ECS, Palma de Mallorca, Spain, 2-4 March 1990. European Cetacean Society, Cambridge. 140 pp.

Hashmi, D.D.K. and Adloff, B.B. 1991. Surface frequency of cetaceans in the Strait of Gibraltar. Pp. 16-17. In *European Research on Cetaceans - 5*. (Ed. P.G.H. Evans). Proc. 5th Ann. Conf. ECS, Sandefjord, Norway, 21-23 Feb 1991. European Cetacean Society, Cambridge. 131 pp.

Marini, L., Consiglio, C., Angradi, A.M., Finoia, M.G. and Sanna, A. 1992. *Cetacei nel Mar Tirreno Centrale: risultati della campagna d'avvistamento 1989-1991*. Roma:107 pp.

Marini, L., Consiglio, C., Sanna, A. and Angradi, A.M. 1992. Some notes on the fin whale (*Balaenoptera physalus*) in the Western Mediterranean Sea. pp. 63-71. In "Whales: Biology - Threats - Conservation" (Ed. J.J. Symoens), Brussels. 261pp.

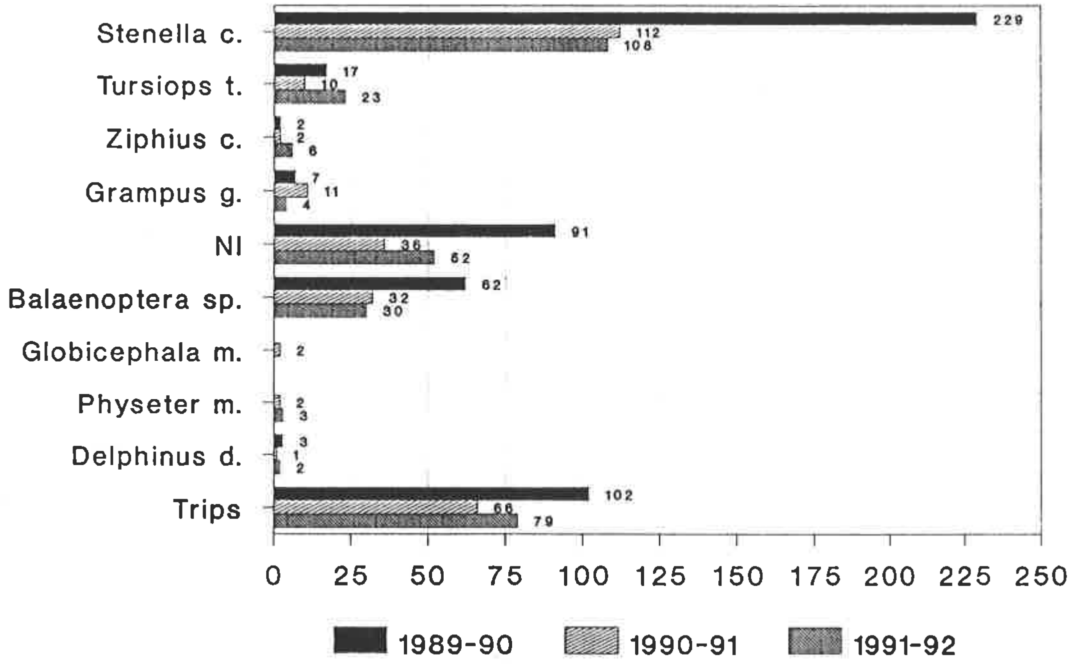

Fig. 1a Sightings by species

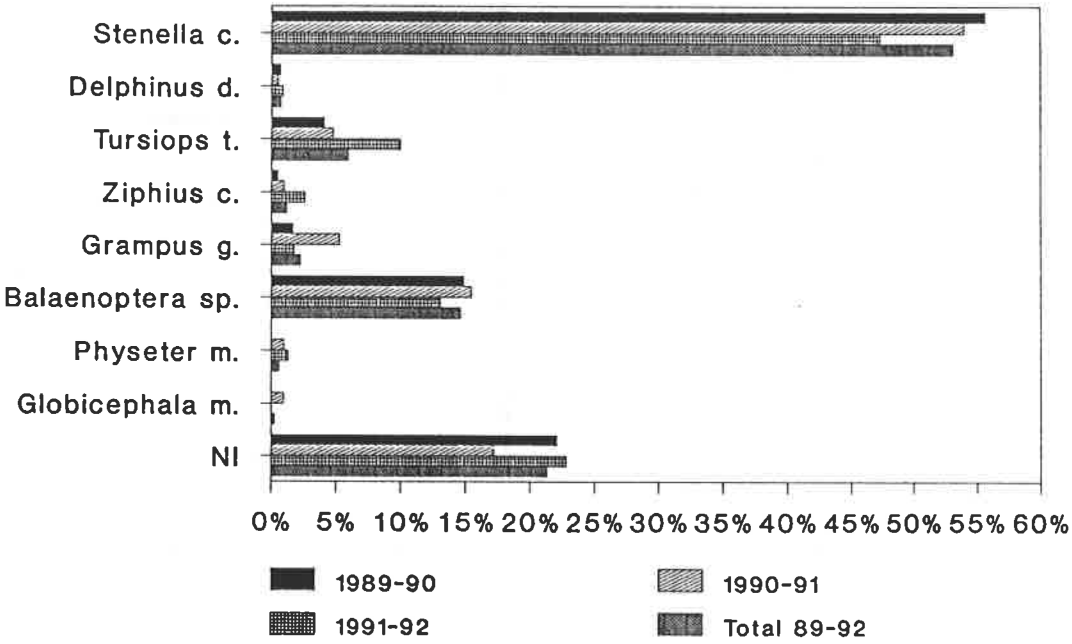

Fig. 1b Sightings by species (%)

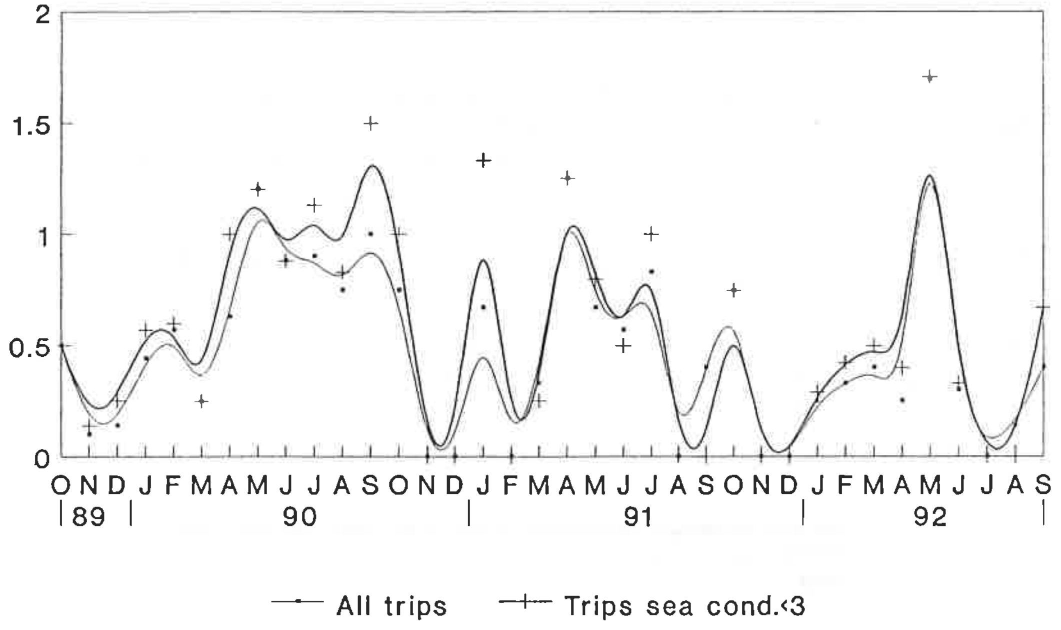

Fig. 2 *Balaenoptera sp.* sightings per trips

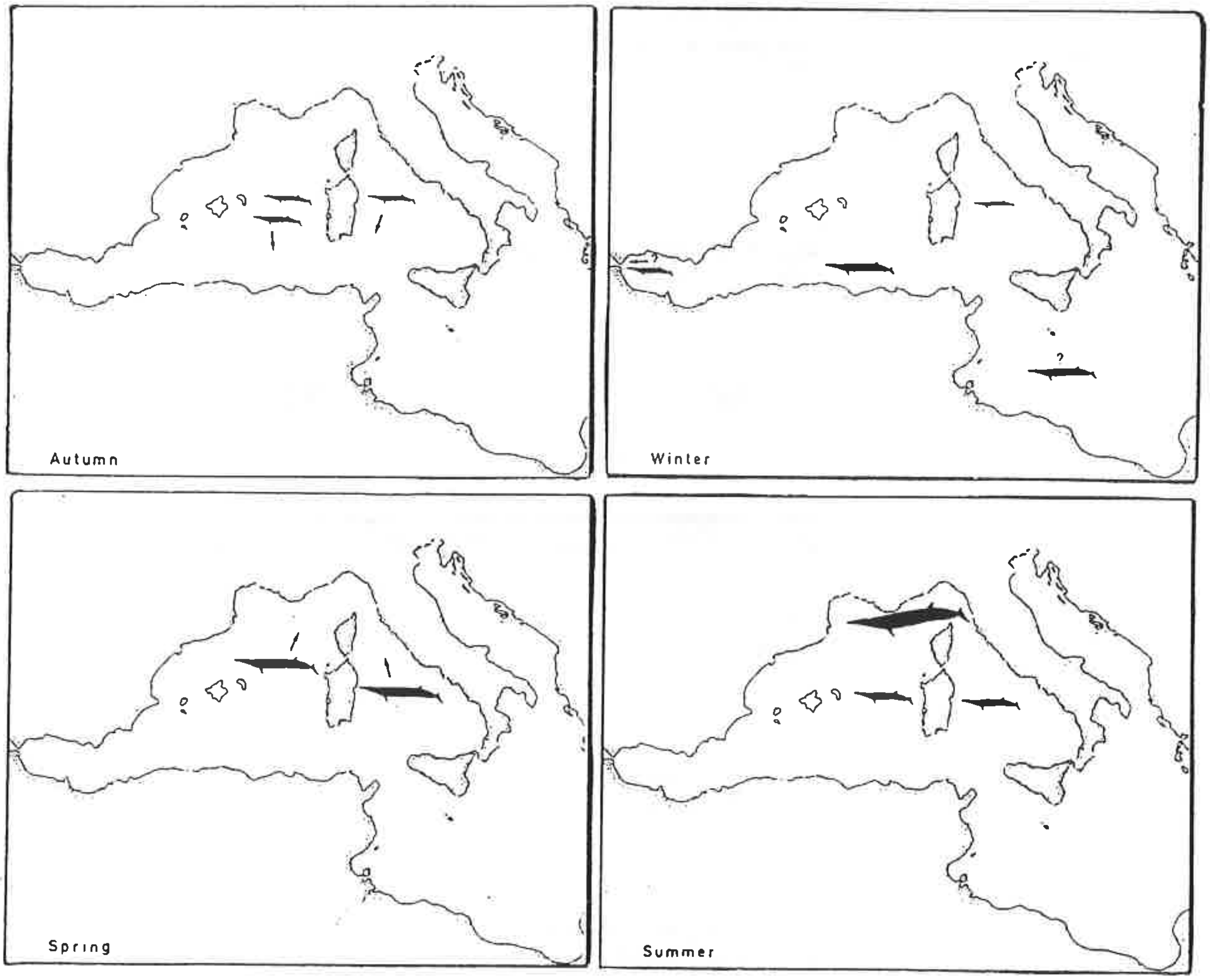

Fig. 3 Distribution of *Balaenoptera* sightings by season

AN ASSESSMENT OF THE PRESENT SITUATION OF CETACEANS AND OF CETOLOGY IN THE AZORES

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Twenty-one species of cetaceans have been reported on Azorean waters, some of which are very common. Several studies have been conducted, during which increased numbers of strandings and sightings were reported, but an organised scheme for the collection of information is still lacking, and many strandings probably never come to the knowledge of interested researchers.

Now that the catch of sperm whales is over, public controversy has focused on the killing of dolphins whose meat is used as food and as bait in the industrial tuna fishery. Catch estimates for these direct killings point to several thousand animals yearly.

CETACEAN SIGHTINGS IN THE AZORES 1987-1991 (EXCLUDING SPERM WHALES)

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From 1987-1991, "Song of the Whale", the research vessel of the International Fund for Animal Welfare, studied sperm whales (*Physeter macrocephalus*) in the waters of the Azorean archipelago, from mid-May to September. A total of 2,227 daylight hours was spent working at sea off the Azores, and 11.2% (249 h) of that was spent with the six most frequently observed species. In addition to sperm whales, twelve other cetacean species were observed. The six most frequently seen were: spotted dolphin (*Stenella frontalis*) (37% of total encounters), common dolphin (*Delphinus delphis*) (22%), bottle-nosed dolphins (*Tursiops truncatus*) (12%), Risso's dolphin (*Grampus griseus*) (9%), short-finned pilot whale (*Globicephala macrorhynchus*) (8%), and striped dolphin (*Stenella coeruleoalba*) (7%).

Infrequently sighted cetaceans included: fin whale (*Balaenoptera physalus*), sei whale (*Balaenoptera borealis*) ,Sowerby's beaked whale (*Mesoploden bidens*), northern bottlenose whale (*Hyperoodon ampullatus*), killer whale (*Orcinus orca*), and false killer whale (*Pseudorca crassidens*).

Group sizes varied between the six most frequently sighted species. Striped dolphin had the largest mean group size (70.17 ± SD 62.0), and Risso's dolphin had the smallest mean group size (12.1 ± SD 12.5).

There was some seasonal variation in the relative abundance of species sighted. Spotted dolphin were the most abundant species in July, August and September, while common dolphin were predominantly seen in June.

Behaviours (bow-riding, travelling, milling and feeding) were systematically recorded from 1989 onwards. Although different species showed contrasting behaviour, no significant seasonal or diurnal differences were found in the frequency of occurrence of behaviours for any species. Patterns of dolphin vocalisations showed marked diurnal variation. Both eco-location clicks and whistles were more frequently heard at night (peaking at 0100 h.) and least through the day (lowest occurrence 1300 h.)

SHORT-FINNED PILOT WHALE ABUNDANCE AND DISTRIBUTION IN SOUTH TENERIFE: PRELIMINARY DATA (JULY TO DECEMBER 1992)

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Boat surveys of short-finned pilot whale (*Globicephala melas*) inhabiting south-west Tenerife, Canary Islands, were conducted between July and December in 1992. Objectives included: (1) examining the abundance and distribution of whales over study area; (2) identifying individual whales using photographs of scars and shape of the dorsal fin; (3) distribution of animals correlated with depth.

Surveys were carried out using a 5 m inflatable boat. School size and age class was evaluated, behaviour recorded and individuals photographed. Photographs were classified based on location of fin notches and catalogued.

The present paper shows the preliminary data recorded during six months of field work.

CANARY ISLAND CETACEAN SIGHTINGS : TOURIST BASED DATA TO LOVE OR LEAVE?

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The validity of data collected on a semi-opportunistic basis by tourist boat activity has been debatable. This analysis shows such data can provide useful information about the distribution and occurrence of cetacean species. Cetacean sightings were recorded from a 65' gaff-rigged ketch during week-long whale-watching expeditions conducted from 22 Dec 1991 to 9 April 1992 in the Canary Islands environs. Crew used standardised data sheets and were trained in cetacean identification and behaviours. Sighting locations were recorded every 15 minutes using GPS Satellite Navigation. Voyages ranged from 28°59.56'N to 27°34.40'S, and 15°42.20'E to 18°51.20'W, encompassing the islands of Tenerife, Gomera, Hierro, Gran Canaria and La Palma, although the majority of effort occurred between west Tenerife and Gomera. Observations occured between 0545 h and 1950 h.

Cetaceans were observed for 119.08 hours (34% of 350 effort hrs) in 94 sightings, during 70 of 100 expedition days, averaging 2.0 hrs per observation day. Short-finned pilot whale (*Globicephala macrorhynchus*) were observed in 48 sightings, totalling 75.5 hrs (63% of all observation hrs): 29% alone, 63% with bottle-nosed dolphins (*Tursiops truncatus*) and 4% with mixed common (*Delphinus delphis*) and bottle-nosed dolphins They were sighted between 28°6.2'N, 27°59.8'S, 17°1.0'W and 16°6.0'E, almost exclusively along the west coast of Tenerife, with only one sighting near Gomera.

When alone, rest was the most common pilot whale behaviour, but in mixed groups, feeding and travel were the most prevalent. Bottle-nosed dolphins were observed in 75 sightings during 91.38 hrs of of which 38.98 hrs (39%) were alone. They ranged from 28°16.8'N to 27°50.0'S, 18°51.2'E to 15°52.7'W; thirty-two sightings were exclusive to Gomera. When alone, feeding and travel accounted for the majority of bottle-nosed dolphin time. Risso's dolphins (*Grampus griseus*), spotted dolphins (*Stenella frontalis*) and common dolphins were sighted on three or less occasions and one lone Cuvier's beaked whale (*Ziphius cavirostris*) was seen near Gran Canaria. Until recently, stranding reports have provided the bulk of information about the distribution and occurrence of cetaceans in the Canary Island archipelago. They hint at a diversity and abundance of species, yet censusing work is in its infancy. In lieu of formalised surveys, sighting reports collected by dedicated observers can provide very useful data, despite problems inherent in opportunistic collection.

SPERM WHALE PHOTO-IDENTIFICATION AND LENGTH-MEASURING PROJECT

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In 1987, a combined whale research station, whale museum and whale-watching station was established in Andenes, Norway. The research method is based on individual photo-identification, behavioural observations and length measurements. One of the research projects of the Whale Centre is a photo-identification project of the sperm whale (*Physeter macrocephalus*), the only project on living sperm whales in Arctic regions. This offers a unique opportunity to study males at higher latitudes while they are segregated from the females. The research is mainly done from the whale safari boats between May and September.

To date, 134 sperm whales have been individually identified and the number of new individual whales is still increasing every year. During 1987-92, only 29% of the 134 whales have been observed on two or more occasions. There have been no matches between Azores and Andenes of individually identified males. In 1991, 7% of the encounters were with males swimming within ten metres of eachother, in groups of 2 to 7 individuals. The tendancy to associate increases almost four times during the summer. The average group-size also increased from May to September.

Using photographs taken from a known height in relation to the horizon it was possible to estimate the length of the live whales. The accuracy of the estimated body length is presented here. The changes in focal length, which change the magnification of the image when focusing, were shown to be included in the confidence limit of the length estimate.

The results of the project indicate that a large proportion of the males, only pass through the area. However, some individuals are present in the study area for the summer and even return for several years in a row. Some of the results might indicate that the males who visit the area could have long migration-cycles, staying in the Arctic longer than one year.

CETACEANS IN BRITISH AND IRISH WATERS: THE WORK OF SEA WATCH FOUNDATION

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INTRODUCTION Since 1973, a voluntary sightings scheme for cetaceans has operated throughout United Kingdom and the Republic of Ireland, organised by the Cetacean Group of the UK Mammal Society (now Sea Watch Foundation) who maintain a central data base. A network of observers was set up and these were encouraged to report cetacean sightings on a regular basis, facilitated by standardised recording forms and a guide to cetacean identification at sea. By 1985, observers in the network numbered about 350 persons. In the last eight years, with widespread public interest and after concerted efforts to develop the scheme, this number increased to over one thousand persons, and continues to rise steadily.

Since the start of the scheme, a total of nearly 20,000 cetacean sightings records have been collected, involving around 100,000 individuals. About 60% of records can be assigned to a particular species on the basis of supporting documentation. Although the majority of sightings have been made on an opportunistic basis, between twenty and thirty observers have been operating regularly, quantifying their effort to provide an index of abundance which is used to monitor annual and seasonal changes in numbers at sample localities (see Fig. 1). Most of these have been land-based, but an increasing number of systematic offshore observations have started to operate in recent years. Observers come from all walks of life and include marine and fisheries biologists, ornithologists, coastguards, lighthouse keepers, meteorologists, aircraft pilots, ferry personnel, Merchant & Royal Naval seamen and members of the oil industry, as well as holiday makers, particularly those owning yachts. Geographical coverage has improved greatly in recent years, although gaps still exist in certain regions, for example the northern Irish Sea and west coast of Ireland.

An analysis of the data was made for the years up to 1978 (mainly dating from 1973, but including regular coverage from some observers, for example weather ships and bird observatories, dating back in some cases to 1958), and published in Mammal Review in 1980. A more recent and comprehensive analysis was carried out for the years up to 1985, under contract to the UK Nature Conservancy Council. The present analysis, contracted by the UK Department of the Environment, undertakes to review our knowledge of the status and distribution of cetaceans in these waters, particularly for the years from 1986-91 with emphasis upon the commoner species, particularly inshore populations of harbour porpoise, common dolphin, bottle-nosed dolphin, and white-beaked dolphin. Where possible, analyses concentrate upon effort-related data but casual records are also used when appropriate for more general distributional studies.

METHODS Sightings are recorded on standardised forms, with identification verified from a description of diagnostic features or from photographs, except in the case of trained observers regularly observing that species, when supporting data for every sighting is no longer required. Effort from land-based sites is quantified either as number of minutes watched or for some sites where that has not been practicable, as number of days watched. For offshore observations, effort is quantified as number of kilometres travelled and generally expressed on an ICES grid cell basis.

All records are transcribed and coded onto a computer data base along with various environmental data such as weather conditions, water depth, sea surface temperature and salinity. The last two are obtained either directly or from monthly charts showing contours of recent averaged values, provided by the Institute of Oceanographic Sciences. Fortran statistical and plotting programs have been developed to enable sightings to be plotted onto computer-drawn maps of the British Isles and surrounding seas. Originally these were written for Apple Macintosh computers but IBM versions are now also available. Programs and manuals for their use have also are available free to bona fide research workers. Individual sightings are either plotted directly or summed as numbers of individuals by grid square (one degree of longitude by half a degree latitude), using the standardised system developed by ICES. For regional analyses, these squares were grouped into seven major sea areas.

Since coverage of the North Sea was previously uneven, effort in recent years has been targeted at improving the scheme along North Sea coastlines (with some west coast sites used for reference), particularly by establishing regular systematic watches using trained observers. To facilitate training of observers, a manual was developed along with a slide training pack on cetacean identification. Regionalisation of data collection was encouraged by the development of local groups, with both indoor and field training sessions. Initial emphasis was placed upon NE Scotland, West Wales and SW England.

RESULTS Twenty-two species of cetacean have been recorded by the sightings scheme since 1973. The nine commonest species in coastal (i.e. continental shelf) waters are (in descending order of abundance): harbour porpoise, white-beaked, bottle-nosed, and common dolphins, long-finned pilot whale, Atlantic white-sided and Risso's dolphin, killer whale and minke whale. In offshore waters, they are: long-finned pilot whale, common dolphin, harbour porpoise, killer whale, bottle-nosed, Atlantic white-sided and striped dolphins, sperm whale and fin whale. The overall status and distribution of the 13 cetacean species most commonly recorded in British and Irish waters is summarised below (see also Fig. 2):

Minke whale (*Balaenoptera acutorostrata*) Widely distributed along the Atlantic seaboard of Britain & Ireland but also regular in northern and central North Sea as far south as Yorkshire. Some indication of an increase since the 1980's with populations concentrated in West and North Scotland. Mainly observed between May and October.

Fin whale (*Balaenoptera physalus*) Distributed mainly along the Atlantic seaboard of Britain and Ireland. Scarce until the mid 1970's, but showing signs of recovery from past human exploitation, particularly during the last five years. Mainly observed June - December.

Humpback whale (*Megaptera novaeangliae*) Rare, with ten sightings in coastal (i.e. continental shelf) waters between 1966 and 1991, all but one since 1980; and four sightings offshore far west of Scotland between 1975 and 1991. Some indication of a recent recovery, further supported by 6 sightings during summer 1992. All sightings from April to September.

Sperm whale (*Physeter macrorhynchus*) Rare, mainly along the Atlantic seaboard of Britain and Ireland, particularly off West and North Scotland. Numbers of sightings have fluctuated between years with peaks in 1975-77 and 1980-81, and an increasing number of group sightings. Most animals seen between July and November (with offshore peaks offshore in July, and in coastal waters between November and December.

Harbour porpoise (*Phocoena phocoena*) Commonest cetacean recorded in British & Irish waters. Widely distributed, though most abundant along the south and west coasts of Ireland, western and northern Scotland including the Hebrides and Northern Isles. Regular though in smaller numbers in East Scotland and NE England, and in some coastal areas within the Irish Sea (mainly off SW Wales). Only small numbers occur in SW England, and the species becomes scarce eastwards along the south coast of England, in the Thames estuary and off East Anglia. General declines noted in coastal areas of the southern North Sea during the 1970's, extending and including some more northern and Atlantic sites during the early

1980's. Some indication of a reversal in this trend in the late 1980's - the present. Resident throughout the year but with peak numbers mainly in March - April and July - November.

Common dolphin (*Delphinus delphis*) Common and widely distributed, mainly off South-west Britain and Ireland, but with some indication of increasing numbers since the mid-1980's farther north off Western Scotland and in the northern North Sea. Although sightings occur in all months, most occur between July and October.

Striped dolphin (*Stenella coeruleoalba*) A warm temperate species, rare in British and Irish waters, but with a recent northwards extension to range (since mid-1980's) indicated by increase in sightings off Western Ireland and NW Scotland. Most sightings between July and December.

Bottle-nosed dolphin (*Tursiops truncatus*) Common on the Atlantic coasts of Ireland, but elsewhere in British waters, only locally abundant, with resident populations in the Irish Sea (particularly Cardigan Bay) and the Moray Firth (NE Scotland), and since 1990, off South-west Cornwall. Rare elsewhere in Britain. Numbers using the Cromarty Firth increased during the late 1980's, but monitoring elsewhere in the Moray Firth only recently started. Off West Wales, numbers in the vicinity of New Quay declined, but again, monitoring elsewhere in Cardigan Bay only recently started. Seasonal movements apparent in most areas, with peak numbers usually between June and August.

Atlantic white-sided dolphin (*Lagenorhynchus acutus*) Common in the northern North Sea and off NW Scotland and Ireland. No systematic trend in abundance, with apparent large increase in numbers sighted during the late 1980's accounted for by a few sightings of very large groups. Although recorded throughout the year, most common from July to September.

White-beaked dolphin (*Lagenorhynchus albirostris*) Common with distribution centred mainly upon the central and northern North Sea, but extending westwards to N and NW Scotland, and southwards towards SW Britain and Ireland. A decline in sightings noted in NW Scotland since the early 1980's. Recorded throughout the year, but with a strong peak in the month of August.

Killer whale (*Orcinus orca*) Widespread and fairly common, with most sightings along the Atlantic seaboard and in the northern North Sea. Relative numbers of individuals seen have declined since 1980, but with little change in frequency of sightings. Sightings occur in all months, but mainly between April and October, particularly June - August.

Long-finned pilot whale (*Globicephala melas*) The commonest cetacean recorded offshore from the continental shelf, but also fairly common and widely distributed in coastal waters, mainly on the Atlantic seaboard and in the northern North Sea. Frequency of sightings increased greatly since mid-1970's. Sightings occur in all months of the year but with peak frequency offshore and along the Atlantic seaboard between June and September, and in the SW Channel approaches and northern North Sea between November and January.

Risso's dolphin (*Grampus griseus*) Fairly common and widely distributed, occurring regularly in coastal waters, mainly along the Atlantic seaboard but also in the Irish Sea and northern North Sea. No indication of any systematic change in status. Most sightings occur between May and September, particularly between July and September.

DISCUSSION & CONCLUSIONS The following species show some indications of increasing numbers in coastal British & Irish waters since 1980: common and striped dolphin, minke, fin, and possibly humpback whale. Those species showing indications of a decline since 1980 include: harbour porpoise (with some evidence of a recovery since 1990 in some areas), white-beaked dolphin and northern bottlenose whale. No overall systematic trend has been observed in the following species: bottle-nosed, Atlantic white-sided and

Risso's dolphins, and killer whale. Frequency of sightings of long-finned pilot whales increased greatly between the mid-1970's and mid-1980's but this increase has since been checked. Sperm whale sightings have fluctuated widely between years with peaks in 1975-77 and 1980-81, but some evidence for a general trend towards increase.

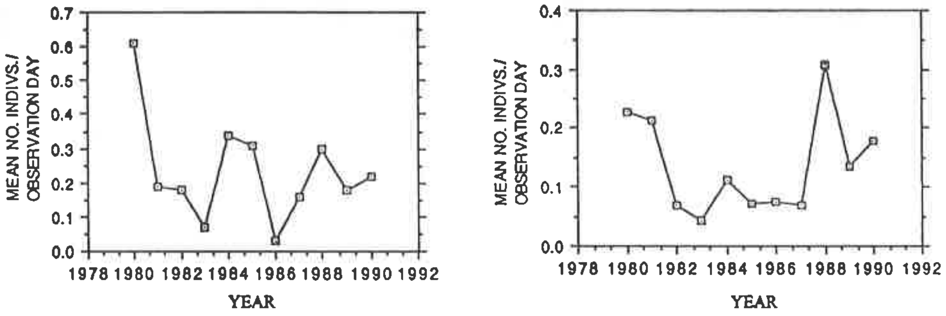
ACKNOWLEDGEMENTS Thanks are due to the network of more than one 1,000 observers who have contributed sightings data, particularly to those operating on a regular basis. Sightings were transcribed and coded onto the computer data base by Rachel Harding-Hill with help from Keith Sumner. The analytical and plotting programs were developed by Stephan Harding, assisted by Ian Gray and Alun Rhishiart. Finally, the analyses, the results of which are summarised here, were made possible by a grant from the UK Department of the Environment whose support is gratefully acknowledged.

REFERENCE

Evans, P.G.H. 1992. Status Review of Cetaceans in British and Irish Waters. UK Mammal Society Cetacean Group (Sea Watch Foundation), Oxford. Report to UK Department of the Environment. 98pp.

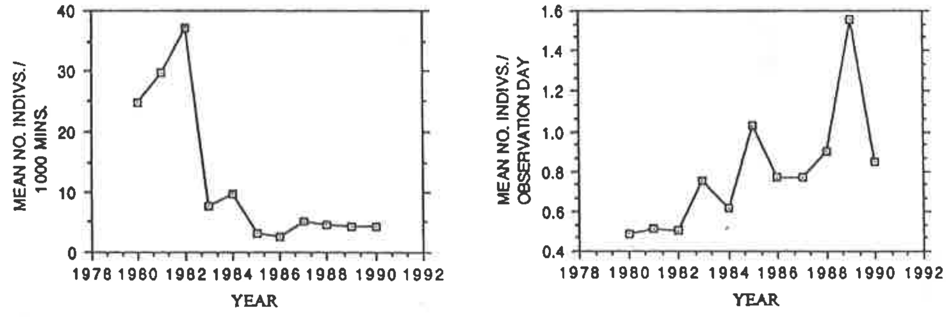
(a) HANDA ISLAND, HIGHLAND

(b) FAIR ISLE, SHETLAND



(c) PETERHEAD, GRAMPIAN

(d) SPURN POINT, LINCS.



(e) DUNGENESS, KENT

(f) CAPE CLEAR, CO. CORK

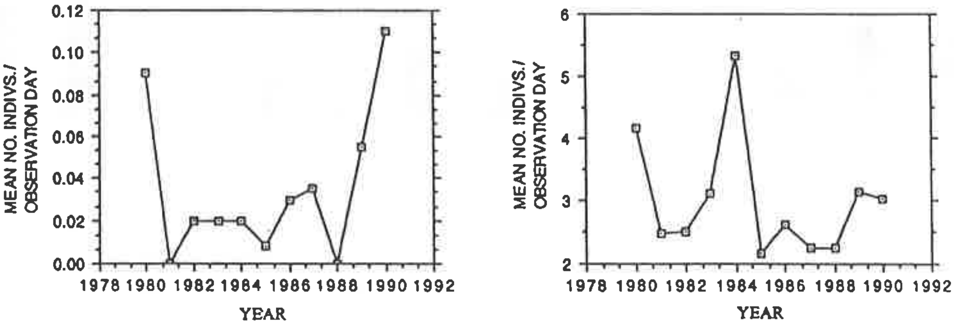
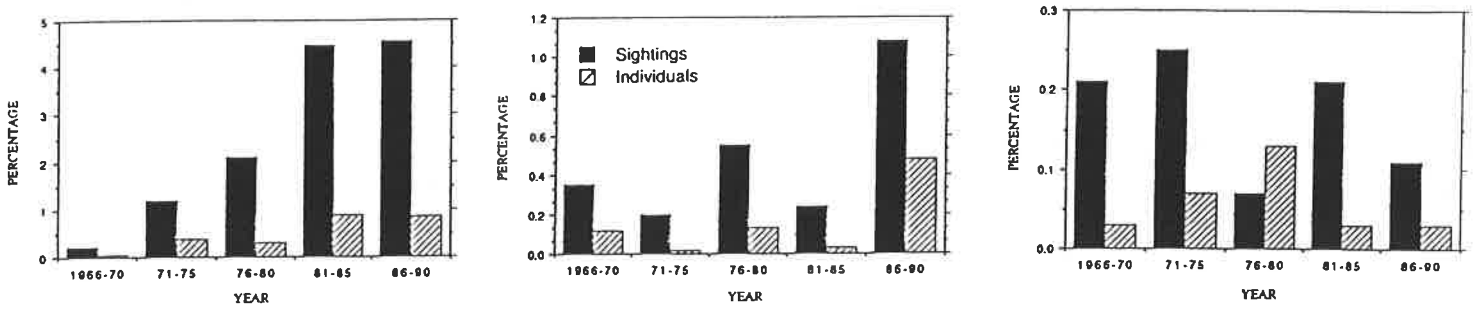
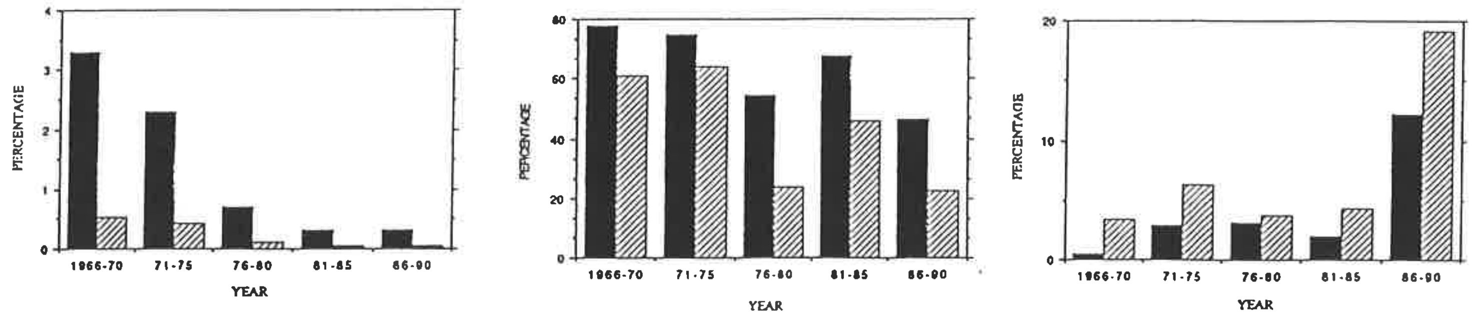


Fig. 1 Annual changes in numbers of harbour porpoises between 1980 and 1990 for six coastal monitoring sites, expressed as mean numbers of individuals either per 1,000 mins. or per day of observation


(a) MINKE WHALE

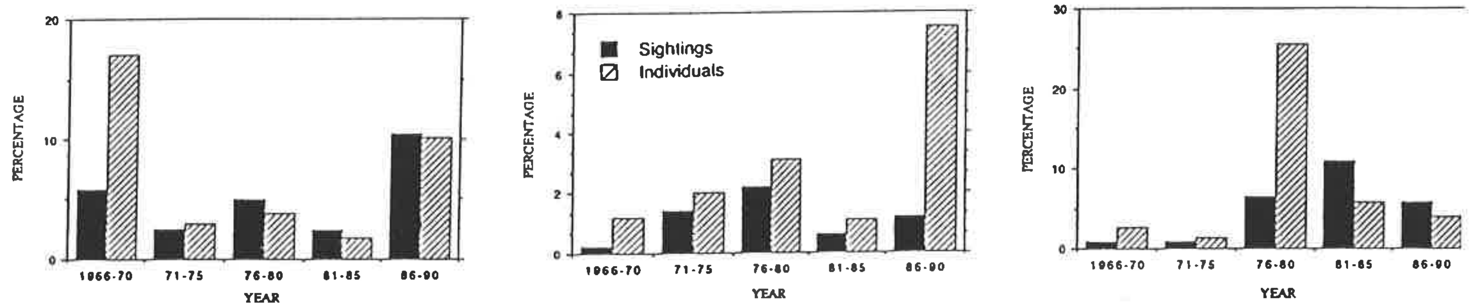
(b) FIN WHALE

(c) SPERM WHALE


(d) NORTHERN BOTTLENOSE WHALE

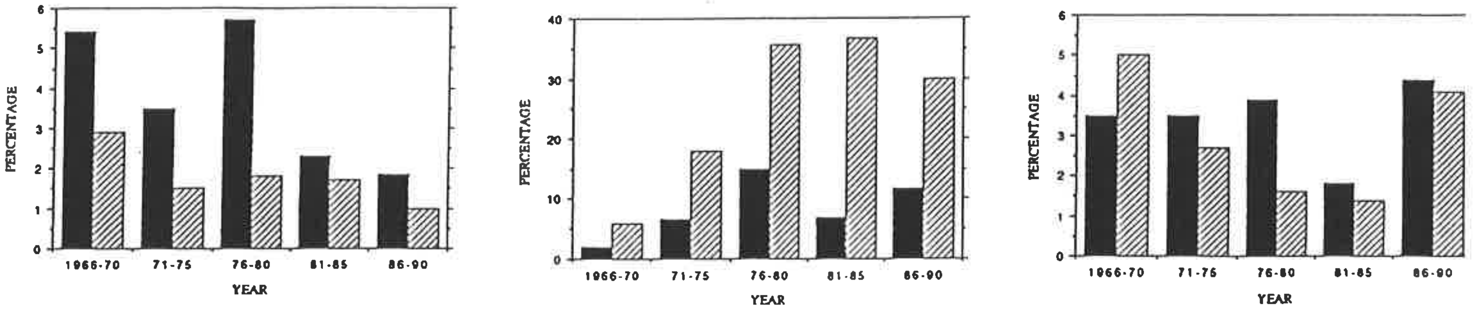
(e) HARBOUR PORPOISE

(f) COMMON DOLPHIN


(g) BOTTLE-NOSED DOLPHIN

(h) ATLANTIC WHITE-SIDED DOLPHIN

(i) WHITE-BEAKED DOLPHIN


(j) KILLER WHALE

(k) LONG-FINNED PILOT WHALE

(l) RISSO'S DOLPHIN

Fig. 2 Variation in the proportion of sightings/indivs. within the total data base for the twelve most commonly recorded cetacean species in Britain & Ireland, over five time periods: 1966-70, 1971-75, 1976-80, 1981-85, and 1986-90

QUANTITATIVE DATA FOR CETACEAN ABUNDANCE IN NW EUROPEAN WATERS

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The Joint Nature Conservation Commitee's Seabirds at Sea Team (SAST) regularly collects observations of seabirds and cetaceans from ships around Britain and adjacent international waters. A standardised methodology is used, designed primarily to survey offshore distributions of seabirds. Animals with a 90° or 180° scan are counted and numbers related to the survey effort (km travelled). Trained observers are used for all surveys which gives a high degree of confidence in the quality of data.

Since the start of the project in 1979, nearly 290,000 km have been surveyed around Britain (Table 1). Most survey effort is from the summer, when there is longer daylight.

Some eleven species of cetacean have been observed during the project. The relative proportion of each species varies in different geographical areas. The white-beaked dolphin (*Lagenorhynchus albirostris*) is most abundant in northern waters and the North Sea, whereas theharbour porpoise (*Phocoena phocoena*) occurs in all areas. Large whale sightings are rare, but have been made most often to the west of Britain.

The common dolphin (*Delphinus delphis*) is the most frequently sighted species to the south-west of Britain and Ireland. A map prepared from the UK SAST database shows that the distribution of common dolphins is localised (Figure 1).

There is some evidence that common dolphins are most abundant in the summer months (June - September; Fig. 2). However, we have so far made no attempt to control for the effects of weather on the visibility of common dolphins in different seasons. Although there appears to be little evidence of large-scale changes in distribution between seasons, localised concentrations do occur, for example off the south coast of Cornwall in winter and in the north Celtic Sea in summer. Dolphins in the latter area were often in association with large flocks of Manx shearwaters (*Puffinus puffinus*). On two occasions, investigations indicated a shallow thermocline in this area, contrasting with highly mixed water closer inshore.

A major analysis is underway on the distribution of white-beaked dolphins and harbour porpoises, and the effects of weather on sightings. Other projects, using similar methods to our own, are underway in Europe. These data have been collated to form a European Seabirds at Sea Database, which includes cetacean observations. The UK data are also used by the UK Cetacean Group sighting scheme.

The Seabirds at Sea Team is presently sponsored by the Joint Nature Conservation Committee, Department of Transport (Marine Pollution Control Unit), Department of Trade and Industry, British Petroleum, Esso, Shell, Elf Enterprise and British Gas.

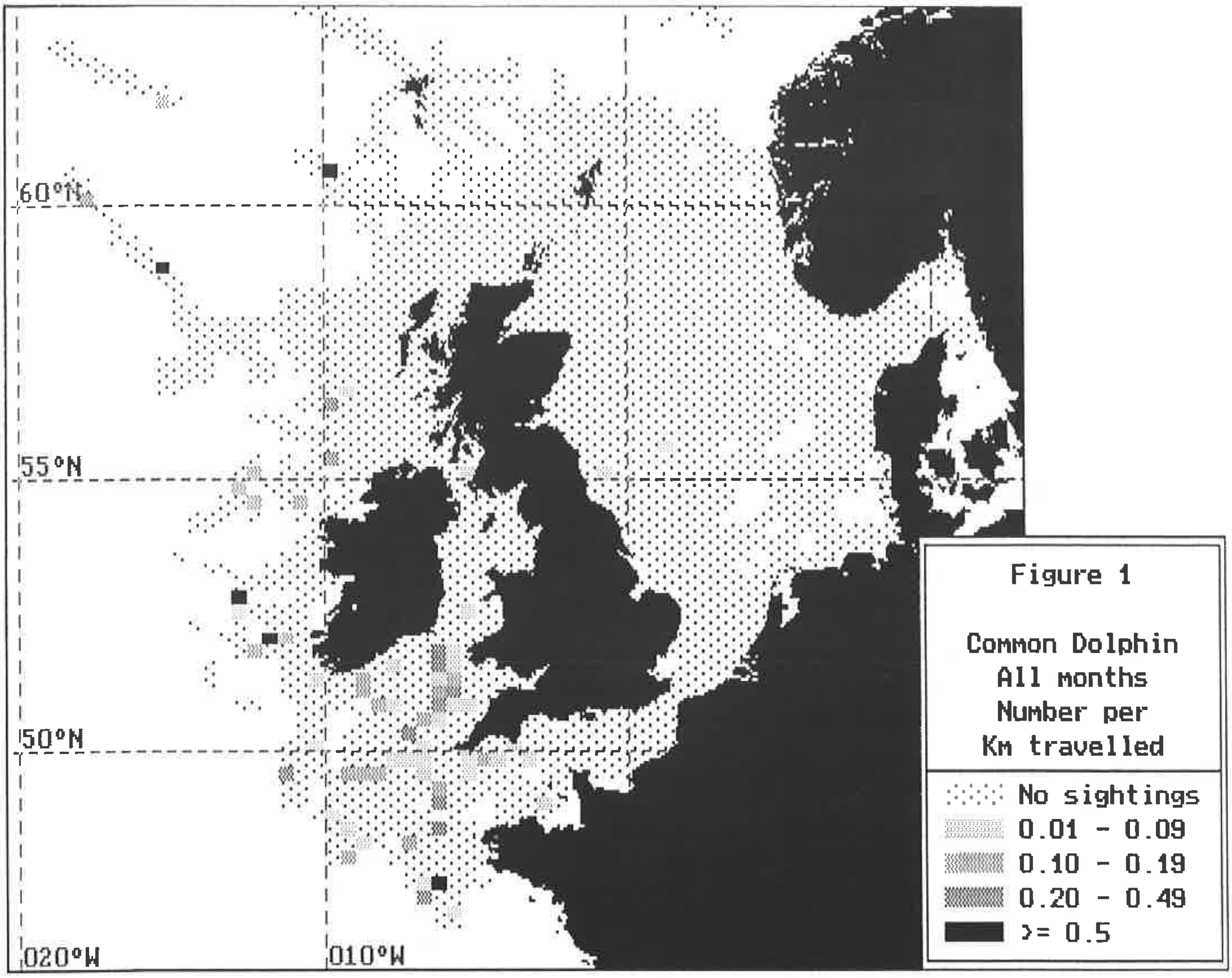

Figure 1

Common Dolphin
All months
Number per
Km travelled

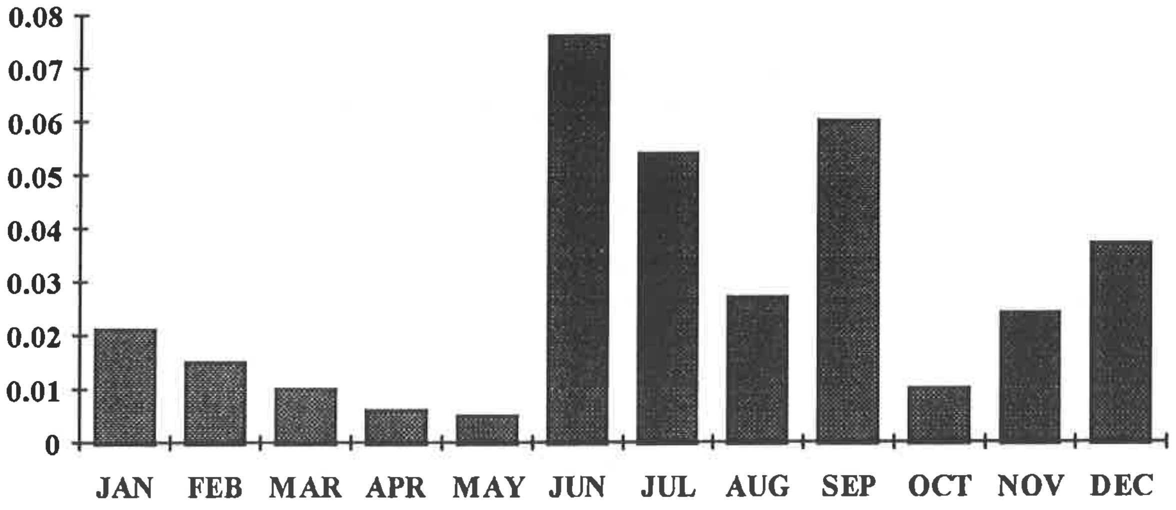

Fig. 2 Number of common dolphins seen per km travelled in South-west waters

Table 1 Total SAST survey effort

	Km travelled
January	14,024
February	19,129
March	18,360
April	23,461
May	31,043
June	30,124
July	41,831
August	45,201
September	24,542
October	16,835
November	13,091
December	11,890
Total	289,531

RARE CETACEANS IN EUROPEAN WATERS : A RANDOM PHENOMENON OR BIOLOGICAL INDICATORS OF OCEANOGRAPHIC CHANGE?

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Apart from the usual resident cetaceans or species regularly visiting a certain area, every area also has some vagrants on its faunal list. These species are not normal inhabitants, but occur 'irregularly' in time. Data from strandings and sightings of unusual cetaceans are analysed from a number of coastal waters in NW Europe (France, Great Britain, Belgium, the Netherlands, Denmark).

Species concerned are most often from oceanic and/or tropical origin (large rorquals, sperm whale, dwarf sperm whales, ziphiids, short-finned pilot whales, Fraser's dolphin,......).

These occurrences do not seem to happen on a random basis, but are more or less grouped in time. This may suggest that most ephemeral appearances have something to do with changes in the environment, whether or not these are short-term oscillations or part of a major trend (global change?).

SUMMARY OF CETACEAN STRANDINGS AROUND THE SCOTTISH COAST DURING 1992

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Records of cetacean strandings have been kept at the Natural History Museum in London since 1913 with reports coming largely through HM Coastguard. In 1991, NHM received reports of seventeen strandings from Scotland.

In January 1992, the SAC Veterinary Services Division was contracted by the UK Department of the Environment to co-ordinate and investigate marine mammal strandings on the coast of Scotland. The aims of this project are to record the incidence of cetacean and seal strandings in Scotland, to carry out Post-mortem examinations on suitable carcasses to establish cause of death, and provide biological data and tissues for dietary, reproductive, and toxicological analyses.

This project is linked closely with a similar strandings project in England and Wales.

A total of 108 animals have been recorded from 101 incidents, including two mass strandings of long-finned pilot whales (*Globicephala melas*) and one mass stranding of Sowerby's beaked whales (*Mesoploden bidens*).

The Harbour porpoise (*Phocoena phocoena*) was the commonest species with 48 individuals being reported.

Five live strandings have been recorded involving 14 animals with the largest being seven long-finned pilot whales which stranded together on the west coast of Lewis.

Results from future years will show if the increase in strandings reports is based on the increased effort to collect this information.

REVIEW OF THE PUBLISHED CETACEAN STRANDING RECORDS ON THE IRISH COAST, 1900-1990.

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INTRODUCTION There is no official cetacean stranding scheme in Ireland. Prior to 1900, isolated reports of stranded cetaceans were published in a number of publications. Between 1913 and 1947, records were reported to the stranding scheme operated by the British Museum. Scharff (1900) produced the first list of stranded cetacea in Ireland, and O'Riordan (1972) updated this list. Since 1981, reports of stranded cetaceans have been published annually in the Irish Naturalists' Journal.

In the present review, stranding records from 1900-1990 were collated and analysed in an attempt to determine any trends in the stranding records.

METHODS The literature was reviewed for records of cetaceans stranded on the Irish coast. Only published records are included in this review. For the present review, a stranding is considered an event and includes both live strandings and those animals washed up dead.

RESULTS 21 species of cetacean have been reported stranded on the Irish coast although the blue whale (*Balaenoptera musculus*) and sei whale (*Balaenoptera borealis*) have not been reported since 1914. Five species of Ziphiidae have been reported: northern bottlenose whale (*Hyperoodon ampullatus*), Cuvier's beaked whale (*Ziphius cavirostris*), Sowerby's beaked whale (*Mesoplodon bidens*), True's beaked whale (*Mesoplodon mirus*) and Gervais' beaked whale (*Mesoplodon europaeus*). Ten cetacean species have been recorded in sufficient numbers for some basic analysis.

The harbour porpoise (*Phocoena phocoena*) is considered to be the most common and widely distributed cetacean species in Irish waters (Fairley, 1981). They have been recorded stranded throughout the present century. However, the number has increased dramatically since the early 1980's (Fig. 1). Although reported from all coasts, 61.5% of records are from counties Cork and Waterford on the south coast which undoubtedly reflects increased recording effort in these areas. Reported strandings peak during November to March which Smiddy (1985) suggests may be related to the herring (*Clupea harengus*) fishery which operates during this period. Reported strandings of white-sided (*Lagenorhynchus acutus*) and striped dolphins (*Stenella coeruleoalba*) have increased during the last decade (Fig. 2). 54% of white-sided dolphin records were reported during 1989 and 1990, and some are thought to be associated with the mackerel (*Scomber scombrus*) fishery (Berrow & Smiddy, 1989; Berrow & Stark, 1990). There has been a significantly higher proportion of male white-sided dolphins reported stranded than females ($X^2_1 = 8.26$, $P<0.001$) which suggests that 'bachelor herds', similar to those recorded in the northwest Atlantic (Sergeant *et al.*, 1980), may be occurring off the Irish coast. The striped dolphin was first reported stranded on the Irish coast in 1985. After re-examination of skulls in the Natural History Museum, Dublin, O'Riordan & Bruton (1986) showed that this species had stranded on at least three occasions prior to 1985 but had been mis-identified as common dolphin (*Delphinus delphis*). Since 1985, striped dolphins have been reported stranded in most years and with increasing frequency. The number of common dolphins reported stranded declined from 1920 to 1950 and none was reported between 1942 - 1962. Since 1976, the number reported has been increasing at a constant rate (Fig. 2). There has been an increase also in the number of pilot whales (*Globicephala melas*) and sperm whales (*Physeter macrocephalus*) reported stranded since the 1960s, and in minke whales (*Balaenoptera acutorostrata*) since the 1970s (Fig. 3). Published sperm whale strandings were reviewed by Berrow *et al.* (1991). The frequency of reported strandings of

Risso's dolphin (*Grampus griseus*) and Cuvier's beaked whale has remained constant throughout the century while the number of reported northern bottlenose whale strandings has declined since the 1950s (Fig. 4).

DISCUSSION Any analysis of stranding records must be treated with caution since many factors can influence the records. The most important factor is the amount of effort put into obtaining records. Since 1970, the number of authors publishing stranding records has increased suggesting that there has been an increase in the number of people reporting stranded cetaceans in Ireland (Fig. 5). Prior to 1981, most cetacean records were reported to museums who then published these records under one name. Between 1981-90, records have been published under the reporter's name and these also show an increase in the number of people reporting stranded cetaceans (Fig. 6). The present analysis suggests that the cetacean stranding data from Ireland is inadequate to assess the status of most species of cetaceans in Irish waters.

The stranding records do suggest that striped dolphins may be stranding on the Irish coast with increasing frequency. If stranded in poor condition, with no visible body markings, striped dolphins can only be distinguished from common dolphins by their skull characteristics which may, as in the past, result in mis-identification. Most of the recent striped dolphin records report the animal in good condition and describe the species' distinctive markings. It is unlikely that striped dolphins, which may have stranded prior to 1980 in good condition, would have been mis-identified as common dolphin, suggesting that the recent increase in striped dolphin strandings reflects a real trend. Striped dolphins in the north-east Atlantic tend to occur in water greater than 1,000m in depth and with a modal surface temperature of 19°C (Forcada *et al.*, 1990). The increase in the numbers of reported strandings of striped dolphins on the Irish coast may reflect an increase in sea temperature as there has also been an increase in the occurrence of some warm temperate fish species off the Irish coast (Quigley *et al.*, 1991).

REFERENCES

Berrow, S. & Smiddy, P. 1989. White-sided dolphin *Lagenorhynchus acutus* (Gray). Ir. Nat. J., 23(4):158-159.

Berrow, S. & Stark, D. 1990. White-sided dolphin *Lagenorhynchus acutus* (Gray). Ir. Nat. J., 23(8):334.

Berrow, S.D., Evans, P.G.H. and Sheldrick, M.C. 1993. An analysis of sperm whale *Physeter macrocephalus* L. stranding and sighting records, from Britain and Ireland. J. Zool., Lond., 230: 333-337.

Fairley, J.S. 1981. *Irish Whales and Whaling.* Blackstaff Press, Belfast.

Forcada, J., Aguilar, A., Evans, P.G.H. & Perrin, W.F. 1990. Distribution of common and striped dolphins in the temperate waters of the eastern north Atlantic. P. 64-66. In *European Research on Cetaceans - 4* (Eds. P.G.H. Evans, A. Aguilar and C. Smeenk). Proc. 4th Ann. Conf. ECS, Palma de Mallorca, Spain, 2-4 March 1990. European Cetacean Society, Cambridge. 140 pp.

O'Riordan, C.E. & Bruton, T. 1986. Notes on the crania of the euphrosyne dolphin *Stenella coeruleoalba* (Meyen) in the collections of the Natural History Museum of Ireland. Ir. Nat. J. 22(4): 162-163.

Quigley, D. T., Flannery, K. and O'Shea, J. 1991. Trigger fish (*Balistes carclinensis* Gemlin 1789) in Irish waters: a biogeographical review. *Biogeography of Ireland: past, present and future.* Trinity College, Dublin.

Scharff, R.F. 1900. A list of Irish Cetacea. Irish Nat., 9: 83-91.

Sergeant, D.E., St. Aubin, D.J. and Geraci, J.R. 1980. Life history and northwest Atlantic status of the white-sided dolphin *Lagenorhynchus acutus.* Cetology, 37: 1-12.

Smiddy, P. 1985. Common porpoise *Phocoena phocoena* (L.) Ir. Nat. J., 21(12): 541.

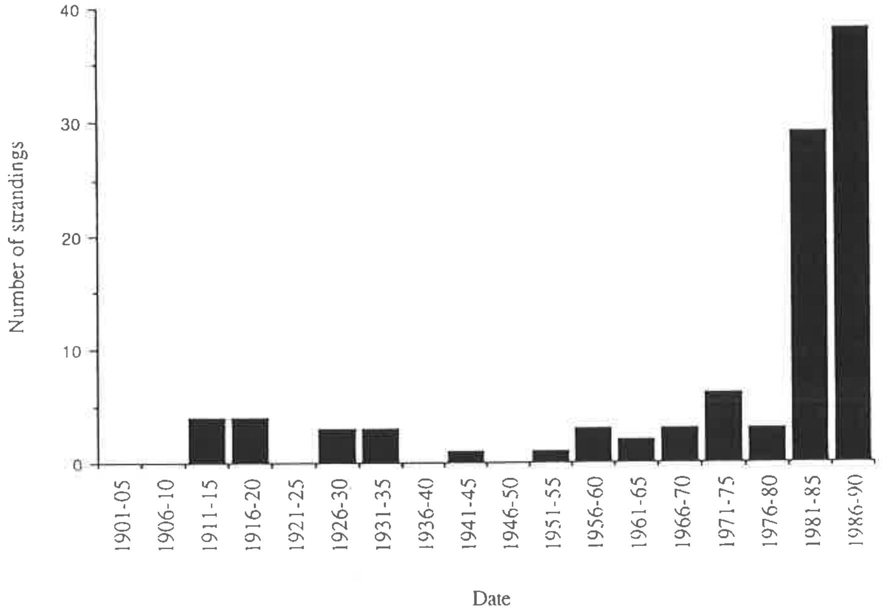

Fig. 1 Frequency of reported strandings of harbour porpoise on the Irish coast, 1900-1990

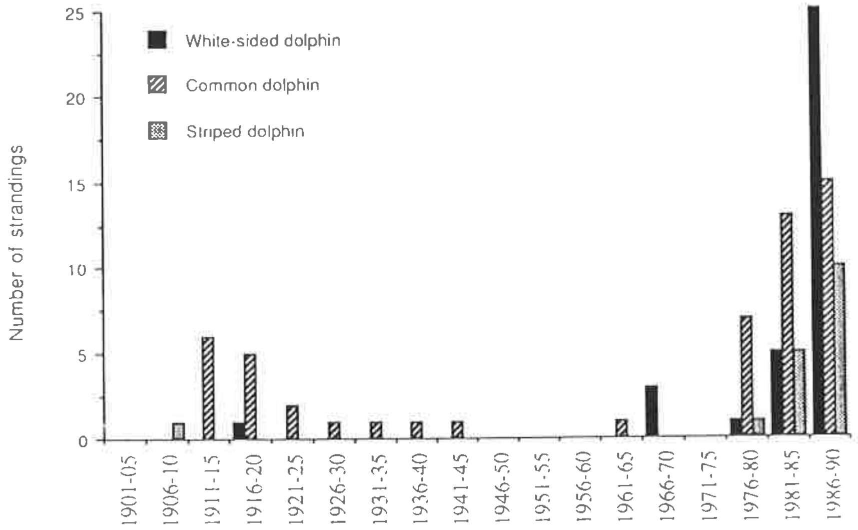

Fig. 2 Frequency of reported strandings of white-sided, common and striped dolphins on the Irish coast, 1900-1990

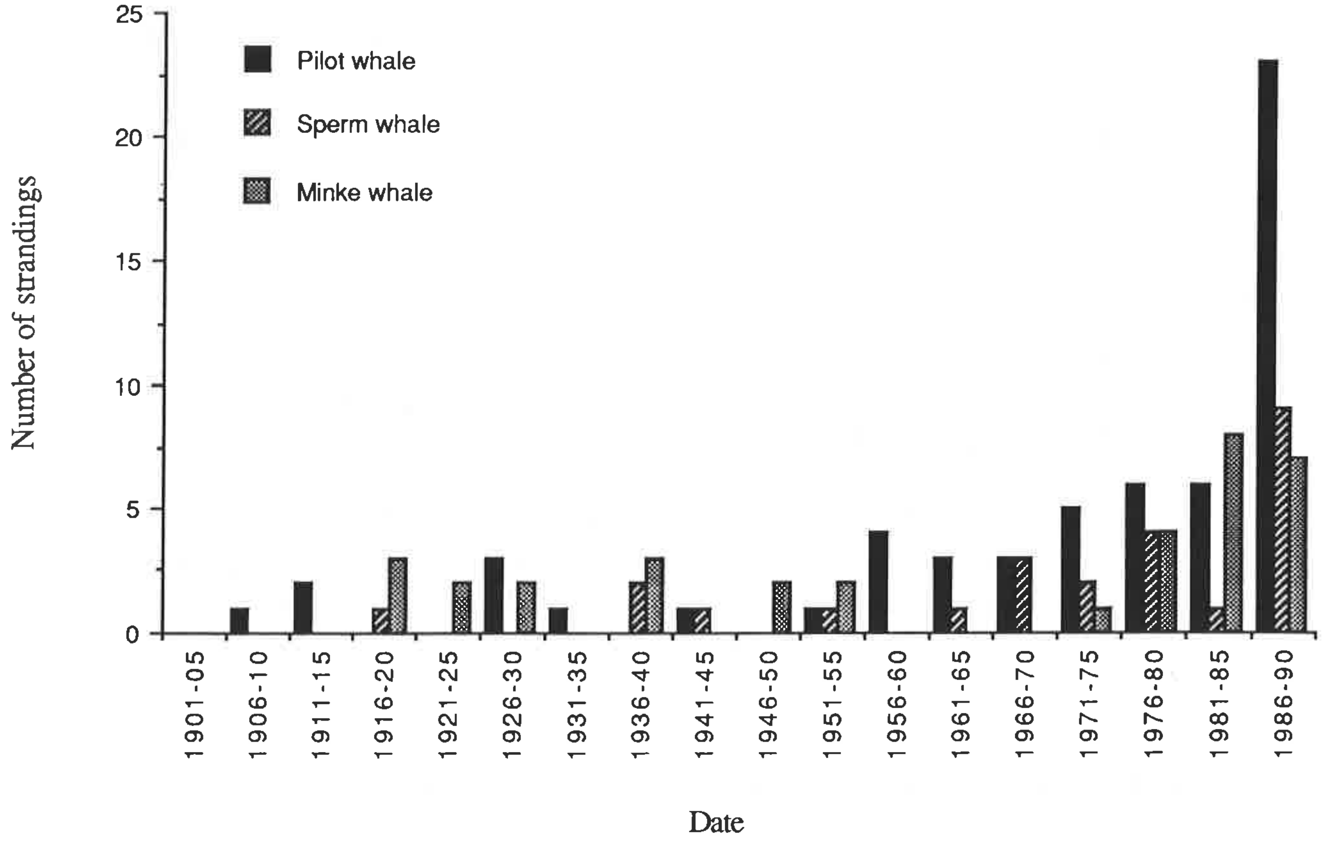

Fig. 3 Frequency of reported strandings of pilot, sperm, and minke whales on the Irish coast, 1900-1990

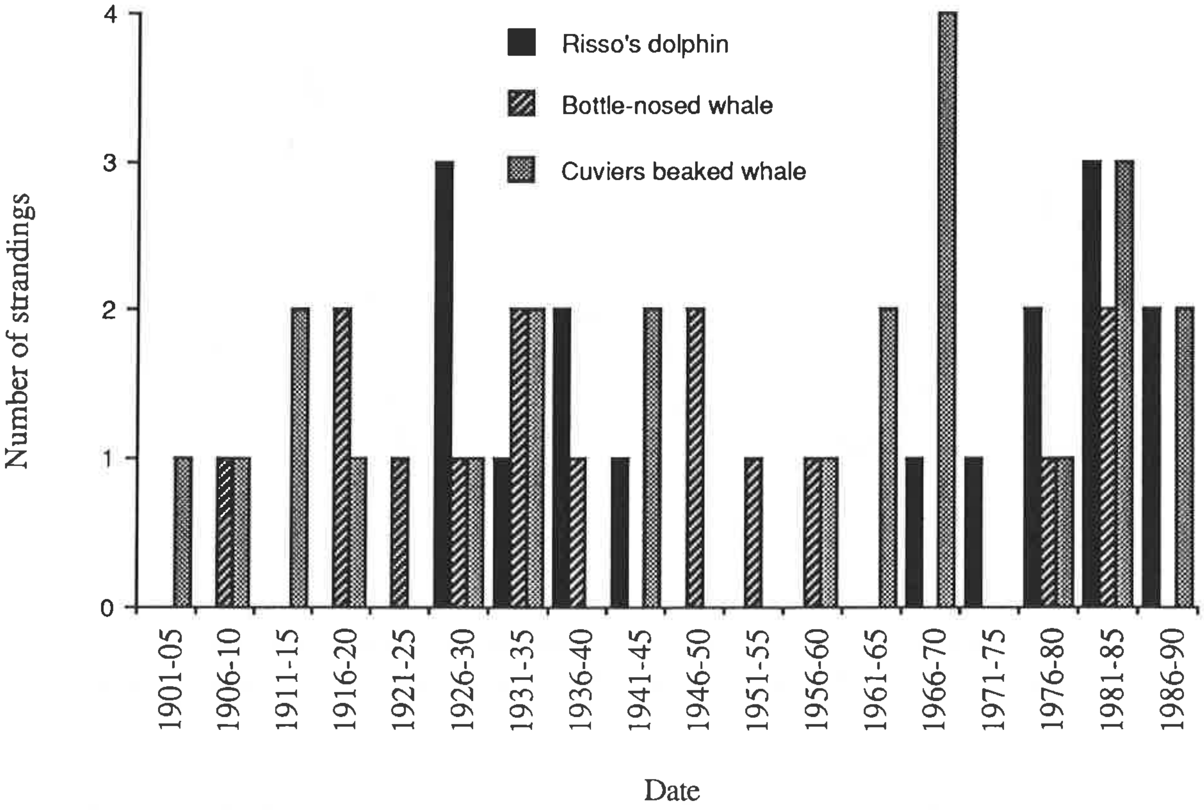

Fig. 4 Frequency of reported strandings of Risso's dolphin, Cuvier's and bottle-nosed whales on the Irish coast, 1900-1990

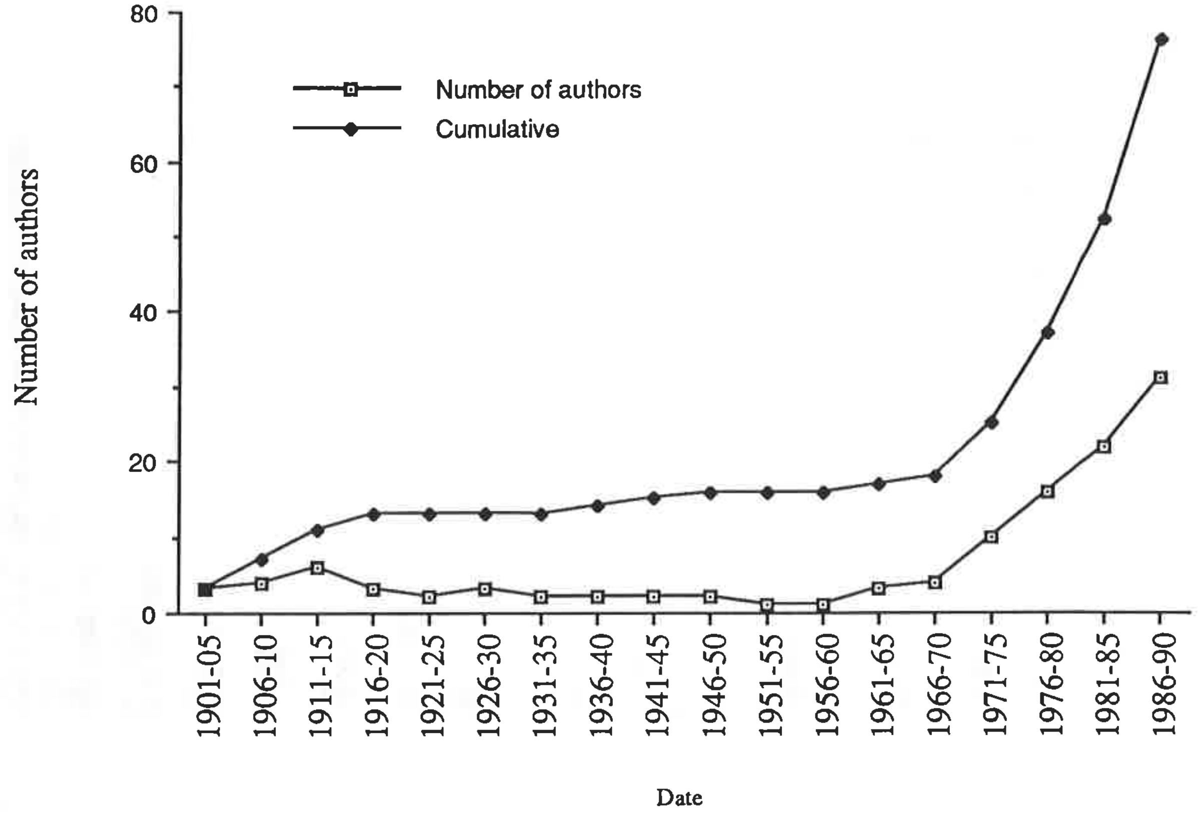

Fig. 5 Number of authors publishing cetacean stranding records from Ireland, 1900-1990

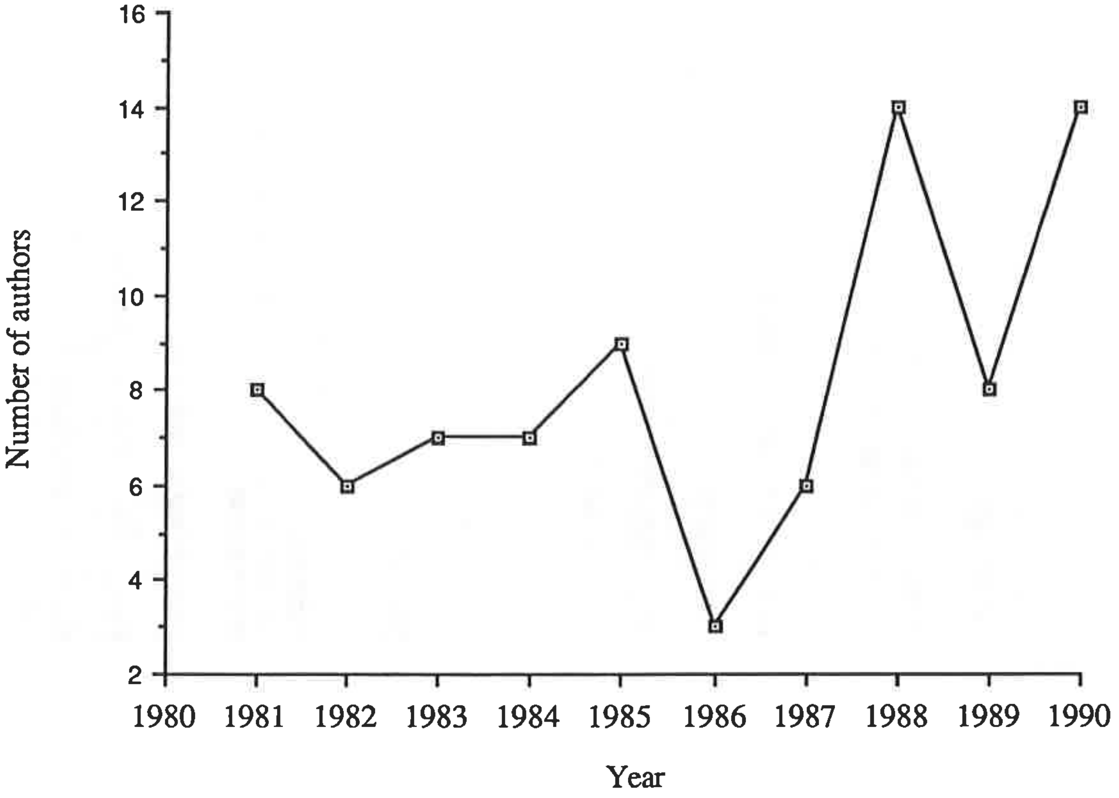

Fig. 6 Number of authors publishing cetacean stranding records from Ireland, 1981-1990

SOME ASPECTS ON CETACEANS STRANDED IN THE NETHERLANDS, 1990-1992

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In 1990, an intensive research programme on cetaceans stranded on the Dutch coast was started, with special emphasis on the general biology, ecology and pathology of the harbour porpoise (*Phocoena phocoena* L.).

The intention of the study is to gather information on the life history, disease and pollutant burden of porpoises in Dutch waters and the differences in these respects between Dutch porpoises and cetaceans from other areas.

An outline of the research project is presented and more detailed information given on stranding frequencies, reproductive status in relation to age, pathological findings, sex-ratio, and stomach contents.

CETACEAN STRANDINGS IN VICTORIA AND TASMANIA, AUSTRALIA, 1970-1990

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The possible causes of strandings of cetaceans on the shorelines of Tasmania and south-eastern Australia over the period 1970 to 1990 were analysed. Appropriate rescue procedures for live-stranded cetaceans were examined and extensive guidelines developed. Major causes of strandings were local geographical features in combination with seasonal animal and climate factors. Successful rescue of live stranded cetaceans required development of a co-ordinated reporting system, use of an assessment team, including a thorough clinical examination and an appropriate rescue phase. Helpful volunteers and equipment were essential as was a final debriefing. The aims of on-beach operations were to minimise suffering of stranded cetaceans, return to the sea as many live cetaceans as possible, to minimise health hazards, and to collect information in a benign manner.

ASPECTS OF DECOMPOSITION OF HARBOUR PORPOISE (*Phocoena phocoena*) CARCASSES: A STUDY CASE IN THE MARINE ENVIRONMENT

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In *post mortem* examinations of carcasses, a first general description of the condition is a useful reference for the following analysis. For this purpose, condition codes of small cetaceans have recently been developed and standardisation attempted, avoiding time frames. In fact, the diversity of the physical and biological environments, which strongly affect the features of decomposition, make the establishment of categories of decomposition and the attribution of a time scale a very complex task, if not impossible. However, this should not suffice to discourage attempts, so long as the particular circumstances are taken into account.

The aim of this study was to describe the stages of decomposition of carcasses of harbour porpoises in the marine environment, by identifying common features and the factors involved in this process.

Fresh carcasses of harbour porpoises were set at the harbour of Helgoland during periods of different water temperatures. The outer aspect, temperature (inside the carcass and water) and the presence of scavengers were recorded underwater and after surfacing.

The main physical factors involved in decomposition are temperature, solar radiation, relative humuduty and currents, which interact with biological agents such as micro-organisms and scavengers. Factors intrinsic to the carcass (e.g. blubber thickness, stomach contents), which probably play a relevant role on decomposition, could not be assessed due to the nature of the experiment. Several stages were identified: tissue lesions, gas bloating, putrefraction, visceral and skeleton exposure.

Carcasses were subject to similar scavenger intensity (number of scavengers per observation). A total of 12 species were recorded. The most abundant were *Carcinus maenas* (25.81%), *Hyas araneus* (22.58%) and *Pholis gunnellus* (19.35%). The variation of the species composition on the harbour porpoises is basically attributed to the seasonality of the scavengers.

BEHAVIOUR OF HARBOUR PORPOISE (*Phocoena phocoena*) CARCASSES IN THE GERMAN BIGHT: SURFACING RATE AND DRIFT ROUTES

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Strandings have been the major source of research fields such as feeding ecology, toxicology, parasitology, and population dynamics (i.e. mortality rates). However, many questions remain unsolved about the nature and factors involved in this phenomenon. For instance, there has been some controversy about whether fresh carcasses of small cetaceans sink or drift. The purpose of this study was to clarify this issue and assess the time frame, as well as the influence of water temperature, on this process.

Fresh carcasses were set in the south harbour of Helgoland in March, May and August. In all cases, the carcasses sank to the bottom (7 m depth) and surfaced after a period of time ranging from 6-55 days. The submersion period varies inversely with the mean water temperature and can well be described by an exponential function. In the case of non-seasonal patterns of the surface currents, carcasses would have less chance of stranding in the cold season, since they remain underwater for an extended period. As a result, mortality rates would be under-estimated in cold seasons, which may contribute to the low frequency of strandings recorded in cold months during 1991 and 1992 in the German Bight.

Another aspect of this study concerns the distribution of strandings, which are highly concentrated around Sylt. Currents have obviously a major role on the stranding phenomenon. However, it is not known to what extent they are responsible for these patterns. As an attempt to elucidate these questions, simulations of the drift of harbour porpoise carcasses were carried out using the operational model for the North and Baltic Seas from Bundesamt für Seeschiffahrt und Hydrographie (BSH). A method to calculate the drift factor of the harbour porpoise was developed. In order to evaluate the use of the model for this purpose, two drift experiments were carried out with porpoise carcasses using radio telemetry. The results are discussed, as well as the use of the model as a tool in assisting the interpretation of strandings, which could be particularly interesting in tracing the origin of mass die-offs.

AN IDENTIFICATION KEY FOR CETACEAN SPECIES USING CHARACTERISTICS OF THE HUMERUS, RADIUS AND ULNA

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Often carcasses of cetaceans are washed onshore missing the head. In a particular stage of decay, the head, which is weighted down by the large skull bone, is ripped from the bloated and drifting body. The head then sinks to the bottom. Due to the missing skull, identification of the washed-up carcass proves nearly, if not completely, impossible. Unlike the head, the humerus, radius and ulna are almost always found. This initiated the search to be able to identify the species by the forearm bones' characteristics.

In 18 museums and research institutes throughout Europe, skeletal remains of the frontal extremities of 197 individuals were examined; a total of 51 different species were able to be registered. Some species were easily identified due to very distinctive features of the bones. A division into different families is also easily done. However, a further division within some families, for example Delphinidae, is only exact for a very few species, due to the very uniform shape and size of the frontal extremities' bones.

This key only applies to adult animals, where the forearm shows no conspicuous joint of the epiphysis due to advanced ossification.

The identification key is not only useful for identifying carcasses of living species washed ashore; it also aids the tentative identification of palaontological finds of recent times, where the skull is not to be found.

PRELIMINARY REPORT ON THE NECROPSY FINDINGS IN SMALL CETACEANS IN GERMAN WATERS

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**Forschungs und Technologiezentrum Westüske, Universtät Kiel, Germany
***Institut für Hygiene und Infektionskrankheiten der Tiere, Universtät Geißen, Germany

INTRODUCTION As part of the German government funded project "Investigation on the abundance, health status and migration of the small cetacean populations in German waters", pathological and microbiological studies on diseases and mortality of small cetaceans were carried out.

174 cetaceans in various states of preservation were dissected during 1991 and 1992. In general, the carcasses from the Baltic Sea exhibited a lower degree of post-mortem changes than those from the North Sea. 106 animals (60%) were in a state of advanced decomposition or maceration unsuitable for further examination. 57 cetaceans were fresh enough to allow complete sampling for histology, microbiology and toxicology. The following report will deal with these cases only.

Fifty-five of the 57 cetaceans were harbour porpoises (*Phocoena phocoena*), the remaining two being white-beaked dolphins (*Lagenorhynchus albirostris*). All the animals from the Baltic Sea were harbour porpoises. Of 30 animals from the North Sea, 28 were harbour porpoises and two white-beaked dolphins.

In the examined group, by-catches were slightly more frequent then strandings. More strandings originated from the North Sea and more by-catches from the Baltic Sea.

The ages of all the animals have not yet been determined. The estimated ages indicate that the majority were adults and subadults. Moreover, sex, condition, and location of findings cannot be related to age of the animals.

Thirty-four females and 23 males have been dissected. From the North Sea, we dissected 21 females but only 9 males, whereas from the Baltic Sea we had 13 females and 14 males. There were more females than males in the group of strandings as well as in the group of by-catches.

The majority of the cetaceans were in good nutritional state. The number of animals in moderate to very poor condition was three times higher in the group of strandings than in the group of by-catches.

GROSS PATHOLOGICAL FINDINGS Net marks could be found in all the by-catches, but in none of the strandings.

All 31 by-caught animals and 10 of the stranded animals had marked pulmonary oedema. Fifty percent of the animals had parasites (nematodes) in the bronchial tract. By-catches and stranded animals were equally affected. Fifty percent of this group also had nematodes in the pulmonary blood vessels. Many of these animals additionally had parasitic nodules and abscesses of the lung. Other types of pneumonia were encountered very rarely.

Of all the cetaceans we found (including those that were too decomposed to be included in the study), we found eight with flatfish stuck in the pharynx and nasal cavities. The flatfish attained a size of up to 27cm. It can be assumed that this caused suffocation of harbour porpoises.

The cardiovascular system exhibited only few lesions. Occasionally, there was cardiac dilation, associated with nematodes in the pulmonary blood vessels and in the heart.

In most of the cases, the alimentary system only showed a moderate parasitic burden. Sometimes we found ulcers or abscesses associated with the parasites. Only a few inflammatory lesions were seen. In 15 cases, we found trematodes in the liver and associated pancreatic nodules or abscesses. In two cases, the pancreas showed trematodes and associated lesions.

Lesions of the bones, joints, muscles and tendons are rare. In two animals, we found adrenal gland cysts and, in three cases, parasites in the eustachian tube and the inner ear.

Gross pathological lesions of the urinary and reproductive system have not been found.

BACTERIOLOGICAL EXAMINATION Routine bacteriological examination of thirty animals yielded no bacterial growth in nine cases, a non-specific mixed-bacterial-flora in twenty cases, and ß-hemolytic streptococci in one case.

CONCLUSIONS According to our findings there is no indication of an epidemic due to a specific bacterial or viral infection. Most of the lesions encountered were associated with parasitic burdens. Abscesses were probably caused by secondary infections.

The by-caught animals were mainly subadults and young currently being weaned, in good nutritional state, showing net marks, pulmonary oedema and in some cases pulmonary congestion.

	By-catch (n=31)	Stranding (n=26)	Total (n=57)
Liver			
Parasites	7	8	15
Parasitic nodules	7	6	13
Abscesses	2	2	4
Liver congestion	0	1	1
Pancreas			
Parasites	1	1	2
Parasitic nodules	1	0	1
Abdominal cavity			
Peritonitis caused by foreign bodies	0	1	1

Table 1 Gross pathological findings for stranded and by-caught small cetaceans in German waters

	By-catch (n=31)	Stranding (n=26)	Total (n=57)
Parasites	10	7	17
Abscesses	2	1	3
Ulceration	3	0	3
Oesophagitis	1	0	1
Gastritis	0	2	2
Enteritis	1	2	3

Table 2 Gross pathological findings in the alimentary system of stranded and by-caught small cetaceans in German waters

	By-catch (n=31)	Stranding (n=26)	Total (n=57)
Pulmonary congestion	15	3	18
Pulmonary oedema	31	10	41
Parasites in bronchial tree	16	12	28
Parasitic nodules	12	11	23
Abscesses	2	4	6
Pneumonia	2	4	6
Flatfishes in pharynx and nasal cavities	1	2	3

Table 3 Gross pathological findings in the respiratory system of stranded and by-caught small cetaceans in German waters

	By-catch (n=31)	Stranding (n=26)	Total (n=57)
Cardiac dilatation	2	4	6
Parasites in pulmonary blood vessels	9	10	19
Parasites in ventricles	0	2	2
Abscess of the aorta	0	1	1

Table 4 Gross pathological findings in the cardiovascular system of stranded and by-caught small cetaceans in German waters

MULTIPLE TRAUMATIC INJURIES TO HARBOUR PORPOISE (*Phocoena phocoena*) FOUND STRANDED ON THE SCOTTISH COAST

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Investigations into the causes of death among stranded cetaceans in Scotland have been conducted by SAC Veterinary Services since 1991.

Significant number of stranded harbour porpoise have been found to have suffered multiple injuries characterised by skeletal fractures and damage to internal organs, particularly lung and liver. External signs of injury have correlated poorly with the extent and degree of internal damage. Interpretation of external signs as indicators of the cause of the internal trauma has highlighted the problem of differential diagnosis but further progress towards identifying the cause or causes of this syndrome will be assisted by understanding the nature and causes of these external signs.

The incidence of the syndrome in Scottish harbour porpoise appears to be in marked contrast to that reported elsewhere in the United Kingdom.

A number of possible causes both natural and man-made exist.

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EXAMINATION OF BODY FAT CONDITION IN HARBOUR PORPOISE FROM BRITISH WATERS

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Harbour porpoises (*Phocoena phocoena*), from both strandings and by-catches in fisheries, have been examined since 1985, and extensively since 1990. Measurements designed to give an index of body fat condition, including body weight and girth relative to body length, blubber thickness and blubber lipid content, have been collected during this period, along with basic biological data on date of death, sex, age and reproductive status. A total sample size of more than 100 individuals, with data on most parameters, has been analysed. The results explore firstly, the most reliable indicators of fat condition; and secondly, the variation in body fat condition in relation to age, sex, reproductive status and season, as well as general nutritional and health status. Two of the most impressive findings are that mid-girth is a more accurate indicator of body weight than length, and that the small juvenile animals are both relatively and actually fatter than adults. The latter point may reflect the greater surface/volume ratios of young and their need for insulation and thermoregulation.

STUDY OF SEXUAL DIMORPHISM IN A MEDITERRANEAN POPULATION OF STRIPED DOLPHINS (*Stenella coeruleoalba*) FOR ANALYSING METRICAL SKULL CHARACTERS

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INTRODUCTION With regard to problems concerning sexual dimorphism in cetaceans, a morphometric study was carried out on the skulls of striped dolphins (*Stenella coeruleoalba*), a species very common in the Mediterranean Sea, to determine the sex of a specimen from differences in skull characters. Externally, the only notable character for distinguishing the sexes is the distance between the anus and genital apparatus. However, it is not possible to isolate the latter from osteological studies or whem specimens are in an advanced stage of decomposition. The aim of this study was therefore to establish significant reference parameters which were not alterable during degenerative post-mortem processes.

MATERIALS AND METHODS The material considered 65 specimins stranded along the Italian coasts from 1981 to 1990, and placed at our disposal by several Italian museums.

63 adults and two young were examined, of which 36 were males, 19 females and ten of indeterminate sex.

Two types of measurements were carried out: (1) 28 external measurements proposed by Cagnolaro *et al.* (1983), were used; and (2) 34 metrical skull characters were examined. They are listed in Table 1, and illustrated in Figs. 1-2, following Perrin (1975).

The measurements were carried out with precision instruments and taken in orthogonal projection. In order to control for accuracy, every specimen was measured at least three times.

After that, the data obtained were tested, making use of "Student's t", Mann Whitney U and ANOVA tests.

RESULTS The results of the analysis of 28 external characters confirm the well known finding that the only significant sexual difference is the distance between the anus and genital apparatus.

At least two parameters deserve further examination on possible differences between the two sexes: the length of rostrum, and the distance from the front end of the junction between the naves and the hindmost point of the margin of the supra-occipital crest.

For those parameters, values were greater in females compared with males, and indicate the possibility that for these characters there is a useful method for distinguishing the sexes by osteology.

REFERENCES

Cagnolaro, L., Di Natale, A. and Notarbartolo Di Sciara, G. 1983. *Guida per il riconoscimento delle soecie animale.*

Perrin, W.F. 1975. Variation of spotted and spinner porpoise (genus *Stenella*) in the eastern tropical Pacific and Hawaii. Bull. Scripps Inst. Oceanogr., 21: 1-206.

Table 1 Skeletal measurements and meristics

1. Condylo-basal length
2. Length of rostrum
3 Width of rostrum at base
4. Width of rostrum at 60mm anterior to line across hindmost limits of antorbital notches
5. Width of rostrum at midlength
6. Width of premaxillaries at midlength of rostrum
7. Width of rostrum at 3/4 length, measured from posterior end
8. Distance from tip of rostrum to external nares (to mesial end of anterior transverse margin of right nares)
9. Distance from tip of rostrum to internal nares (to mesial end of posterior margin of right pterygoid)
10. Greatest pre-orbital width
11. Greatest post-orbital width
12. Least supra-orbital width
13. Greatest width of external nares
14. Greatest width across zygomatic processes of squamosal
15. Greatest width of premaxillaries
16. Greatest parietal width
19. Greatest length of left post-temporal fossa, measured to external margin of raised suture
20. Greatest width of left post-temporal fossa at right angles to greatest length
21. Major diameter of left temporal fossa proper
22. Minor diameter of left temporal fossa proper
23. Projection of premaxillaries beyond maxillaries measured from tip of rostrum to line across foremost tips of maxillaries visible in dorsal view
24. Distance from foremost end of junction between nasals to hindmost point of margin of supra-occipital crest
25. Length of left orbit- from apex of pre-orbital process of frontal to apex of post-orbital process
26. Length of antorbital process of left lacrimal
27. Greatest width of internal nares
28. Greatest length of left pterygoid
29. Greatest width of anterior overhang of supra-occipital crest
30. Greatest length of bulla of left tympano-periotic
31. Greatest length of periotic of left tympano-periotic
32. Length of upper left tooth row
33. Number of teeth (upper left)
34. Number of teeth (upper right)
35. Number of teeth (lower left)
36. Number of teeth (lower right)
37. Length of lower left tooth row
38. Greatest length of left ramus
39. Greatest height of left ramus at right angles to greatest length
40. Length of left mandibular fossa, measured to mesial rim of internal surface of condyle

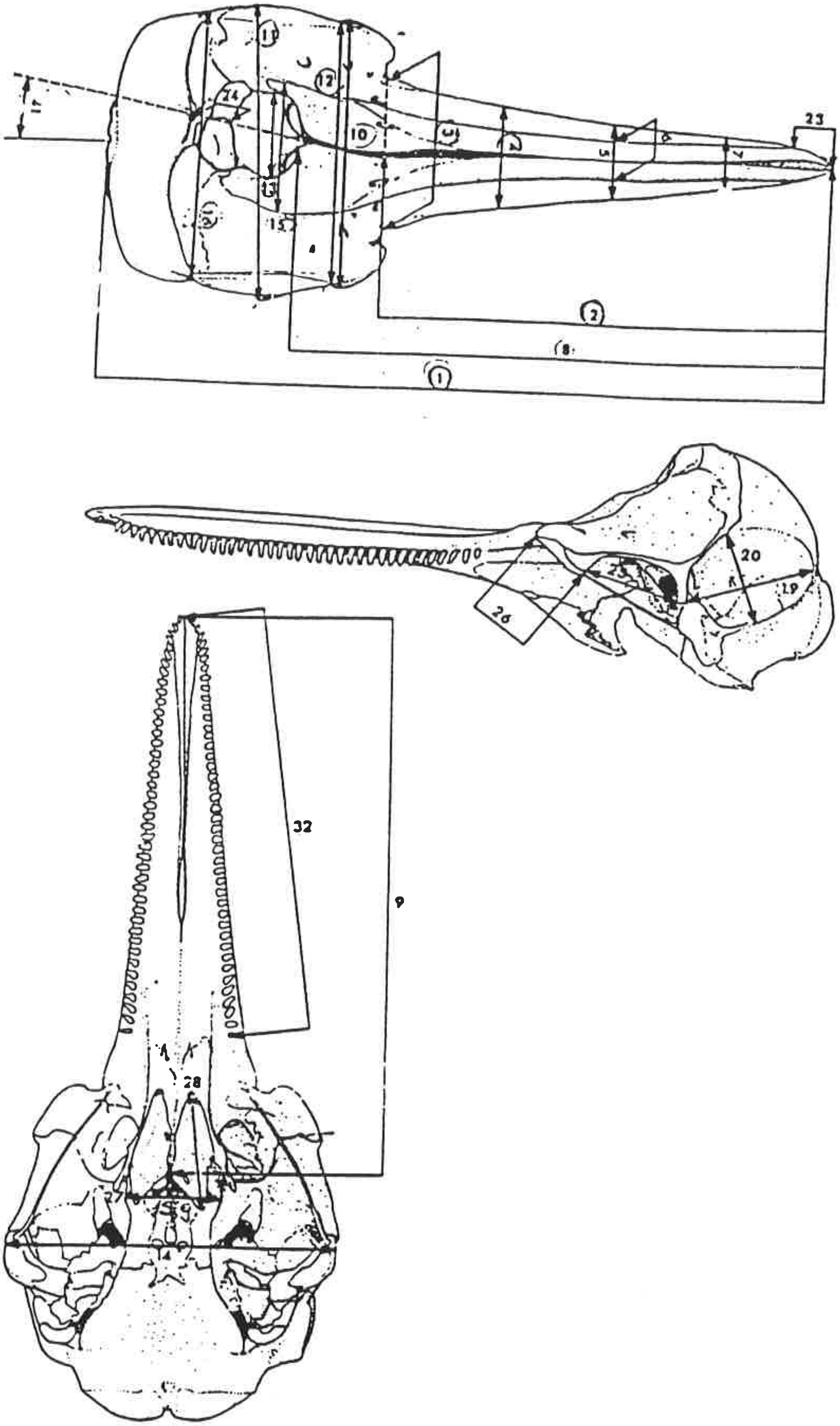

Fig. 1 Measurements of the cranium

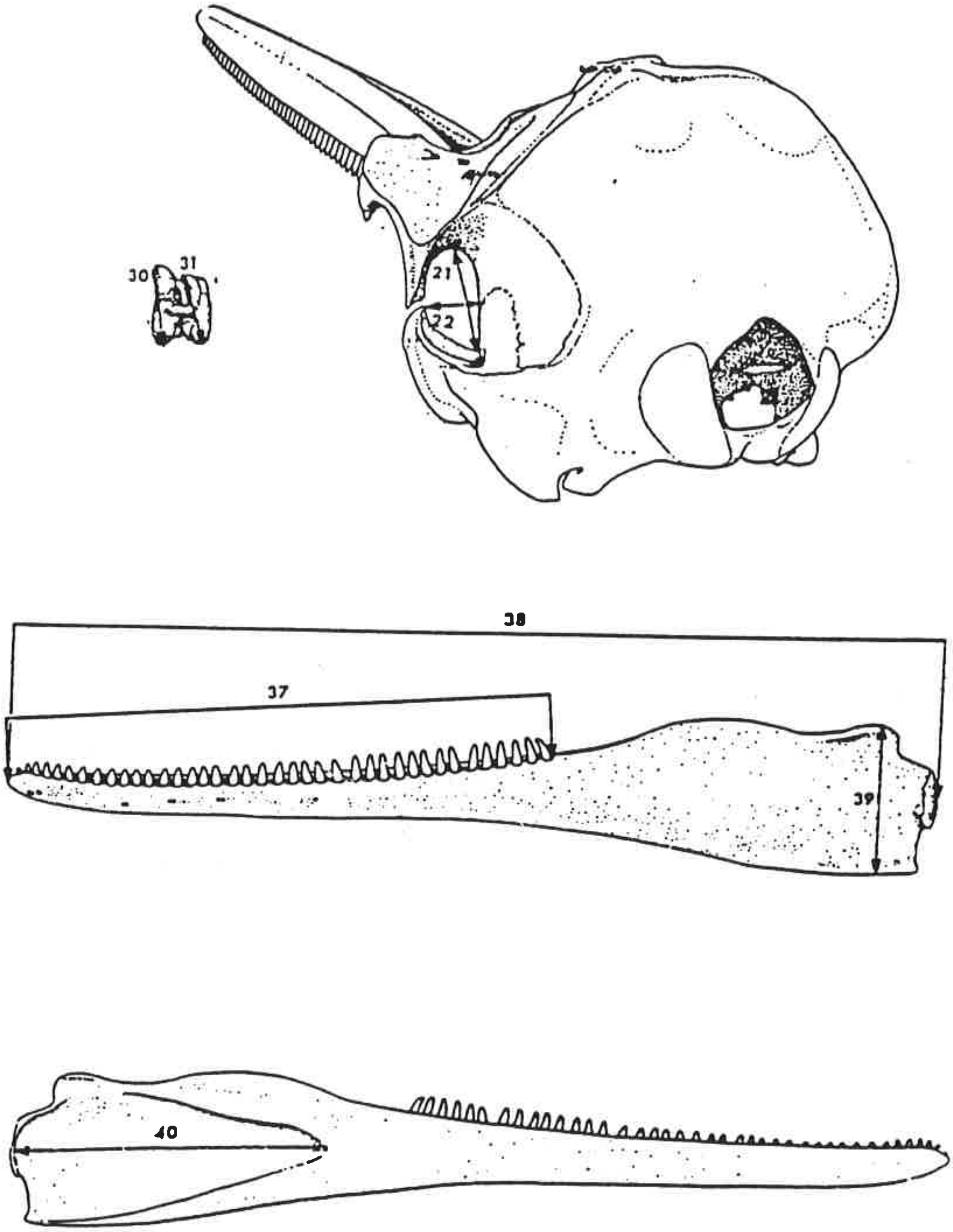

Fig. 2 Measurements of the temporal fossa and mandible

ARE THE EPIZOITS BIOLOGICAL INDICATORS OF THE MEDITERRANEAN STRIPED DOLPHIN DIE-OFF?

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From 1990 to 1991, a viral epizootic affecting striped dolphins (*Stenella coeruleoalba*) was underway in the Mediterranean. This disease caused the death of several thousand dolphins. A period of slow movement previous to death has been hypothesised.

82 striped dolphins stranded between July 1990 and January 1991 in the Spanish Mediterranean coast were examined for ectoparasites and epizoits. Six crustacean species were detected: *Syncyamus aequus, Penella sp., Conchoderma virgatum* and *Xenobalanus globicipitus* are well known on striped dolphins. However, *Lepas pectinata* and *Lepas cf. hillii* had never been reported on cetaceans. The prevalence of *X.. globicipitis* on the striped dolphins analysed during the same months in 1980-90 and 1991-92 is 30.0% (n=18 stranded animals), versus 51.5% on those affected by the epizootic (n=64). This increase is not statistically significant and could be explained for methodological reasons. However, if we assume that a decrease in swimming speed would increase the probability of the colonisation of this barnacle, it could be expected that a great deal of the infrapopulations would partly or totally be formed by juveniles. Distribution of shell and pseudocapitulum sizes of each *X. globicipitis* infrapopulation suggest that they are young, their average sizes being far lower than those attained by the barnacle on this dolphin, as we have observed in other cases. The occurrence of particular species, such as *Lepas pectinata, L. cf. hillii* and *C.virgatum*, commonly associated with fixed or slow-moving objects, also support the restricted movement hypothesis. There is no definitive evidence showing any change in the population of *X.. globicipitis* due to the epizootic. Nevertheless, our data suggest changes of this or other species.

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PRELIMINARY DATA ON THE HELMINTH FAUNA OF HARBOUR PORPOISE IN BRITISH WATERS

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The parasites of harbour porpoises (*Phocoena phocoena*) in British waters have been poorly studied. The aim of this preliminary study is to characterise the helminth fauna of porpoises in this area, with special attention to the digestive tract parasites.

During 1989 and 1990, parasites from 37 harbour porpoises stranded or by-caught in British coasts were collected. No ectoparasites were found. Six endoparasite species were detected: *Pholeter gastrophilus,* in the main and pyloric stomach, *Anisakis simplex* in the stomach; *Campula oblonga* in liver and pancreas; *Stenurus minor* in air sinuses; and *Pseudalius inflexus, Torynurus convolutus, Halocerus taurica* and *Halocerus sp.* in the lungs. Cestode sp. seemed to appear only occasionally.

The prevalence of digestive tract parasites increases rapidly during the first years of the host's life. From 2-3 years old, the prevalence is 100% in *A. simplex* and *C. oblonga,* but it fluctuates in *P. gastrophilus*. *A. simplex* and *P. gastrophilus* are eurixen parasites in cetaceans. Prevalences of these species in pilot whales from the Faroe Islands (North Atlantic), show a similar model, despite the different habitats and food habits of both odontocetes. However, the geographical distribution of these parasites species could not be uniform along the North Atlantic. In a complementary study, *P. gastrophilus* was not detected in harbour porpoises from Fundy Bay (Canada). *A. simplex* seemed to present lower intensities.

This project was supported by the British-Spanish Integrated Action Nº 165 A.

PARASITIC METAZOA OF STRIPED DOLPHIN (*Stenella coeruleoalba* Meyen, 1833) (CETACEA: DELPHINIDAE), STRANDED ALONG CENTRAL ITALIAN COAST

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The striped dolphin (*Stenella coeruleoalba*) represents the most common species of cetacean stranded along the Italian coasts. A parasitological study on seventeen specimens of stranded along central Italian Tyrrhenian coasts during the period 1985-91 has been carried out.

The taxonomic and systematic studies have enabled the identification of the following metazoan parasites:

HELMINTHS - Digenea: *Campula rochebruni, Campula palliata* and *Pholeter gastrophilus.* Cestoda: *Tetrabothrium forsteri, Strobicephalus triangularis, Monorygma grimaldii* (larvae) and *Phyllobothrium delphini* (larvae). Nematoda: *Skriabinalius sp.*

CRUSTACEA - Copepoda: *Pennella sp.* Amphipoda: *Syncyamus aequus.* Isopoda: *Meinertia parallela.*

NEW DATA ON THE *Anisakis simplex* COMPLEX (NEMATODA, ASCARIDIDA, ASCARIDOIDEA), PARASITE OF CETACEANS

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Isozyme studies were carried out on the morphospecies *Anisakis simplex*, which parasitises at the adult stage the stomach and intestine of various cetacean hosts. Genetic variation and gene flow were analysed in populations from various parts of its range.

The data obtained show that *A. simplex* s.l. includes at least five distinct biological species, reproductively isolated but not differentiated at morphological level (sibling species). They were designated *A. simplex s.s.*, *A. peareffii, A. simplex* C, *A. simplex* D and *A. simplex* E (Nascetti *et al.*, 1986 and unpublished). As to their definitive hosts, *A. simplex s.s.* has been recovered in white-beaked dolphin (*Lagenorhynchus albirostris*), long-finned pilot whale (*Globicephala melas*) and harbour porpoise (*Phocoena phocoena*), from the North-east Atlantic; in white-beaked dolphin and white whale (*Delphinapterus leucas*) from the North-west Atlantic; and in false killer whale (*Pseudorca crassidens*) and harbour porpoise from the Pacific coast of Canada.

A. pegreffii has been identified in bottle-nosed dolphin (*Tursiops truncatus,*) sperm whale (*Physeter macrocephalus*) and Cuvier's beaked whale (*Ziphius cavirostris*) from the Mediterranean Sea. *A. simplex* C has been found sympatrically with *A. simplex s.s.* in false killer whales from Pacific Canada. No data are so far available on the definitive hosts of *A. simplex* D and E, which were recovered only as larvae in fish from the Falkland Islands and Tasman Sea respectively.

PARASITES AS BIOLOGICAL TAGS OF STOCKS OF FRANCISCANA (*Pontoporia blainvillei*)

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The franciscana (*Pontoporia blainvillei*) is a small South American odontocete species, whose populations suffer a high number of annual by-catches in all the countries where this species is distributed. In order to evaluate the impact of the traditional fisheries, more information about the stocks of Franciscana is needed. In this context, parasites can be used as stock or migration tags of their hosts.

The aim of this study is to investigate the existence different stocks of franciscana in Argentina and Uruguay, comparing their helminth fauna in both regions. Forty-five dolphins from Cecochea and Claromecó (Buenos Aires Province) were analysed for parasites. Such animals were obtained during spring and the beginning of summer 1988-1990. Five helminth species were detected: *Polymorphus cetaceum, Polymorphidae* sp., *Ansakis simplex, Pholeter gastrophilus* and a new species of genus *Hadwenius*. Comparing these results with previous information from Uruguayan dolphins off Punta del Diablo coast, it seems that: (1) there are obvious differences in the intensity of *P. cetaceum* ; (2) *A. simplex* may occur only in Argentina, and *Contracaecum sp.* and/or *A. typica* only in Uruguay; (3) there are possible differences in the intensity of *Hadwenius* sp.; and (4) the rest of the species, which have a very low prevalence, are also different for each region. These results suggest that different stocks of franciscana may exist in Argentinian and Uruguayan waters (separated by the Plata River) associated with sedentary habits, at least during spring.

This project was supported by grants from the DGICYT project N°PB87-146-C2-2

A SURVEY OF PCB LEVELS IN THE BLUBBER OF HARBOUR PORPOISES AND COMMON DOLPHINS FROM AROUND THE COAST OF THE UNITED KINGDOM

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INTRODUCTION Since 1990, the UK Department of the Environment has funded a project to improve the quality and quantity of information obtained from stranded and incidentally caught small cetaceans from around the UK coast. As part of this project, blubber samples from 98 harbour porpoises (*Phocoena phocoena*) and 33 common dolphins (*Delphinus delphis*) were monitored for a number of organochlorine (OC) compounds. OC's are of particular concern because (1) they are highly lipophilic and bioaccumulate up through the food chain and (2) they persist in the environment since they are not readily broken down, and they are known to have adverse effects in a number of species including reproductive failure in common seals (*Phoca vitulina*) (Reijnders, 1986). Marine mammals, as top predators, are particularly at risk from these chemicals.

The levels of OC's in blubber are thought to be dependent on a number of factors including sex, age, location, health status, nutritional status and time between death and sampling (see Aguilar, 1987). The effects of the first three of these factors are considered in this contribution while the other effects are considered by Kuiken *et al.* (this volume).

MATERIALS AND METHODS A sample (c. 5g) of a complete cross-section of blubber was collected from the same site, namely anterior to the dorsal fin, placed in a hexane-washed jar and stored at -20°C until analysis. All the analytical and quality control procedures were according to Allchin *et al.* (1989). Briefly, the analysis was as follows: blubber was ground up finely with anhydrous sodium sulphate and then extracted with hexane for 4 hrs in a Soxhlet apparatus. An aliquot of the extract was subjected to both alumina and silica chromatography prior to GLC and mass spectrometry analysis for the following OC's: PCB congeners 18, 28, 31, 44, 47, 49, 52, 66, 101, 105, 110, 118, 128, 138, 141, 149, 151, 153, 156, 158, 170, 180, 183, 187, 194, numbered according to Ballschmiter & Zell (1980), dieldrin, Hexochlorobenzene, *a*- and *y*- hexachlorocyclohexanes, DDT, DDE and TDE (also known as DDD). The total PCB figure represents the sum of the individual 25 congeners measured, which represents approximately 60-70% of the total based on Arochlor 1254 equivalents, and the ICES 7 figure represents the sum of the congeners 28, 52, 101, 118, 138, 153 and 180, recommended by ICES as a basis for inter-laboratory comparisons.

Age was determined by counting the annual growth rings in teeth (Lockyer, in press). For some statistical tests, the animals were placed in one of three age-classes, namely 0-2, 3-6 and >6. The geographical locations where the animals were found were divided up into six areas: (1) West Scotland (1 porpoise); (2) East Scotland, including Shetland (12 M and 12 F porpoises); (3) East England (19 M and 13 F porpoises, 1 M and 1 F dolphin); (4) the English Channel (5 M and 5 F porpoises, 9 M, 13 F & 2 other dolphins); (5) the Irish Sea (15 M and 16 F porpoises); and (6) West Ireland (1dolphin).

RESULTS Tables 1 and 2 show the overall OC levels and ranges encountered in the blubber from dolphins and porpoises respectively. The amounts of hexane extractable lipid were high from both species and there were no significant variations due to sex, location or age. The levels of PCB showed great variation between individuals of both porpoises (0.1-

139.8 mg/kg lipid) and dolphins (2.8-98.6 mg/kg). Further statistical analyses were concentrated on the PCB results from porpoises since the sample size was larger. Because of its positively skewed nature, the data were log transformed. Analysis of variance (general linear model) of the relationship between the level of PCB's and age (or age-class), sex and location was performed, and the differences between means determined with the SNK test. There were significant differences due to sex ($F=3.97$, $p<0.05$) and geographical area ($F=15.18$, $p<0.001$), those in area 2 (East Scotland) having lower levels than those in areas 3,4,5. Fig. 1 shows the average PCB levels by area and sex for porpoises. As can be seen, the males tended to have higher levels than the females in all areas considered apart from the Channel.

The effects of age or age-class were not significant using the above models, but if the results were considered separately by sex (model log(pcbs) = area, age-class), then the trend was for the levels to increase significantly in males, but remain steady in females as the animals grew older (Fig. 2).

The principal congeners of those measured were # 153, # 138, # 149, # 187, # 180 in both dolphins and porpoises, and these six accounted for two-thirds of the total measured. Any differences in PCB congener patterns due to species, sex, age, location, etc. have not yet been investigated.

CONCLUSIONS There is a wide variation in OC levels in the blubber of small cetaceans from around the UK coast. Of the OC's measured, the comparative concentrations (using arithmetic means) were PCBs > DDE > Dieldrin > TDE > DDT > HCB > *y* HCH > *a* HCH in porpoises, and PCBs > DDE > DDT > Dieldrin > TDE > HCB > *y* HCH > *a* HCH in dolphins.

Preliminary statistical analysis of the PCB results shows that males tend to have higher levels than females in both dolphins and porpoises, and that geographical area also influences the result, with porpoises from East Scotland having significantly lower levels than porpoises from other areas. PCB levels tended to increase with age in males but remain fairly steady in females, although, overall, the effect of age on PCB levels was not statistically significant. Overall, the PCB congener patterns were similar in both species although some differences were apparent. The inter- and intra-species related differences are undergoing more detailed analysis.

REFERENCES

Aguilar, A. 1987. Using organochlorine pollutants to discriminate marine mammal populations: a review and critique of the methods. Mar. Mamm. Sci., 3: 242-262.

Allchin, C.R., Kelly, C.A. and Portmann, J.E. 1989. Aquatic Environment Protection: Analytical Methods 6: Methods of analysis for chlorinated hydrocarbons in marine and other samples. MAFF, Lowestoft.

Ballschmiter, K. and Zell, M. 1980. Analysis of PCB's by glass capillary chromatography. Fresenius Z. Anal. Chem., 302: 20-31.

Lockyer, C. (In press). A review of the factors involved in zonation in odontocete teeth and an investigation of the likely impact of environmental factors and major life effects on harbour porpoise tooth structure. Rep. Int. Whal. Commn. (Spec. Issue).

Reijnders, P.J.H. 1986. Reproductive failure in common seals feeding on fish from polluted coastal waters. Nature, Lond., 324: 456-457.

Table 1 OC concentrations (arithmetic A and geometric G means) in porpoise blubber
Values are in mg / kg hexane extractable lipid

	n	A mean	St.Dev	G mean	Range		
PCBS : ICES7	98	12.9	14.5	6.7	0.1	-	82.4
PCBS : ALL 25	98	21.8	24.8	11.0	0.1	-	138.7
HCB	97	0.42	0.34	0.25	0	-	2.0
αHCH	39	0.07	0.07	0.05	0.01	-	0.17
γHCH	41	0.20	0.13	0.14	0.01	-	0.51
DDE	96	4.24	4.85	2.21	0.04	-	26.7
TDE	43	2.20	1.92	1.40	0.10	-	7.3
DDT	42	1.40	1.89	0.54	0.02	-	7.8
DIELDRIN	41	4.19	3.56	2.50	0.17	-	13.4
% LIPID	98	84	9	84	52	-	95

Table 2 OC concentrations (arithmetic A and geometric G means) in common dolphin blubber
Values are in mg / kg hexane extractable lipid

	n	A mean	St.Dev	G mean	Range		
PCBS : ICES7	33	23.3	12.9	17.5	1.7	-	57.7
PCBS : ALL 25	33	40.2	22.1	30.7	2.8	-	98.7
HCB	32	0.24	0.17	0.14	0.02	-	0.81
αHCH	23	0.13	0.08	0.11	0.01	-	0.32
γHCH	22	0.23	0.11	0.22	0.09	-	0.75
DDE	33	8.12	8.35	4.06	0.31	-	40.5
TDE	23	1.25	0.58	1.15	0.04	-	2.7
DDT	23	3.18	3.23	1.41	0.06	-	13.4
DIELDRIN	23	1.71	1.07	1.43	0.03	-	6.7
% LIPID	33	82	8	81	59	-	94

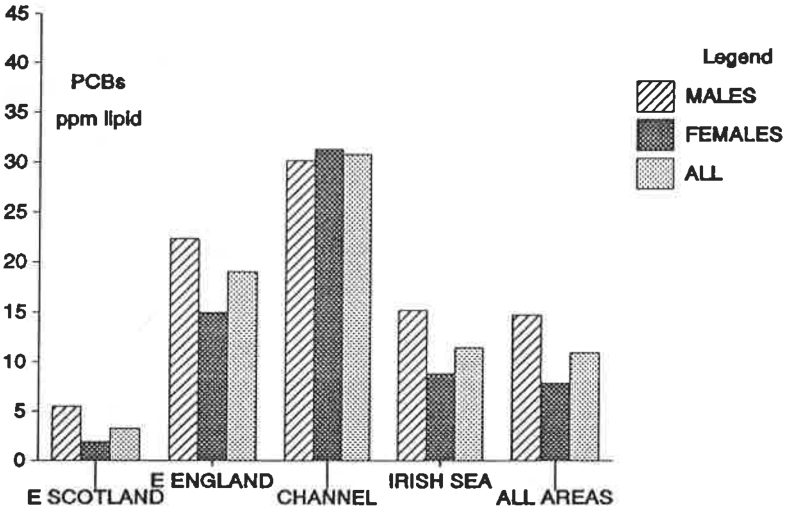

Fig. 1 Chart showing geometric mean PCB levels in porpoises by sex and area

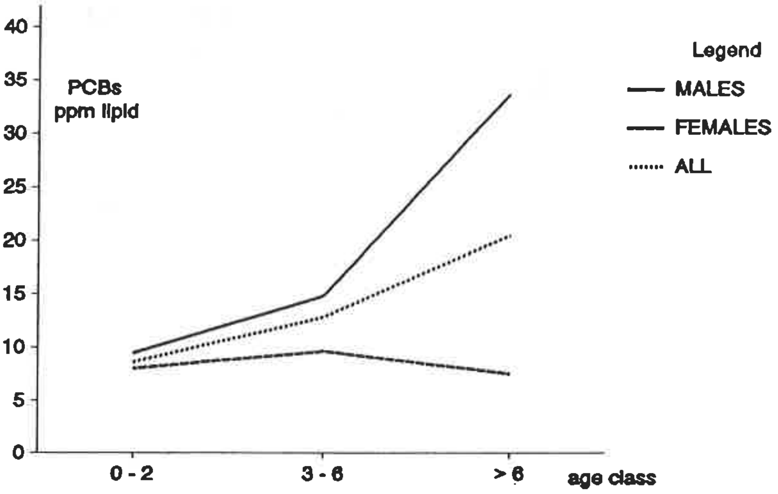

Fig. 2 Relationship between geometric mean PCB levels in porpoise with age-class and sex [as determined by the general linear model log(pcbs)=sex, age-class]

IS THERE A LINK BETWEEN PCB LEVELS AND CAUSE OF DEATH IN HARBOUR PORPOISES (*Phocoena phocoena*)?

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INTRODUCTION It has been suggested that PCBs may have increased the susceptibility of harbour seals in the Dutch Wadden Sea (Brouwer *et al.*, 1989) and striped dolphins in the Mediterranean Sea (Aguilar and Raga, 1990) to microbial and parasitic infections due to their immunosuppressive effects. The main objective of this study was to examine the hypothesis that PCBs increase the risk of harbour porpoises dying from an infectious or parasitic disease as a result of immunosuppression. For this purpose, we compared levels of PCBs between harbour porpoises that died from the above causes, and those that died from physical trauma.

MATERIALS AND METHODS The 68 carcasses of the harbour porpoises (*Phocoena phocoena*) used in this study were found in England and Wales between 1990 and 1992, either stranded on the coast, floating in the water, or entangled in fishing nets.

Cross-sectional samples of blubber adjacent to the dorsal fin were stored at -20°C until analysis was carried out. The levels of the following contaminants were measured according to Allchin *et al.* (1989): HCB, alpha-HCH, gamma-HCH, p,p'-DDE, p,p'-TDE, dieldrin, and 25 individual chlorobiphenyls. The sum of the 25 chlorobiphenyl congeners measured (="total PCB's), and the sum of congeners # 28, # 52, # 101, # 118, # 138, # 153, and # 180 (="ICES 7 PCBs) were also calculated. The standard body length, body girth, and blubber thickness were recorded (Anon., 1961). The body girth and blubber thickness were measured immediately anterior to the dorsal fin.

Pathological examination was carried out according to a standardised protocol (Kuiken and Baker, 1991). The harbour porpoises were divided into five disease groups, based on their probable causes of death: acute physical trauma, including entanglement in fishing nets (A); infectious or parasitic disease (B); starvation (C); miscellaneous (D); and not established (E).

Body condition was estimated by the use of various measures: body weight, body girth, blubber thickness, and percentage of hexane extractable lipid in the blubber sample for toxicological examination (= %HEL). There was a significant correlation between body length and the above parameters. To correct for this, the residuals from the regression equation between the log values of these measures of body condition and body length were used. In the text these are referred to as relative body weight, relative body girth, and so on, because they allow comparisons of the body condition between carcasses of different length.

All continuously distributed data were logarithmically transformed, and the associations between the following parameters were tested using bivariate product-moment correlation coefficients and analysis of variance (Sokal and Rohlf, 1981): body measurements (weight, length, girth), measures of body condition, age, sex, season found (October-March or April-September), region found (West Scotland, East Scotland, East England, South England, West

England and Wales), state of decomposition, method of storage, disease group, levels of individual chlorinated hydrocarbons, ICES 7 PCBs, and total PCBs.

RESULTS To test the hypotheses that PCBs increase the harbour porpoise's susceptibility to death from an infectious or parasitic disease, we compared the PCB levels between disease group A (N=23) and B (N=24). The difference in PCB levels (ICES 7 PCBs: $F_{1,45}=2.13$, NS; total PCBs: $F_{1,45}=2.06$, NS), or levels of any of the other chlorinated hydrocarbons measured, was not significant. There were also no significant correlations between relative measures of body condition and levels of PCBs, or those of any of the other chlorinated hydrocarbons. Of the other parameters measured, only age was significantly correlated with chlorinated hydrocarbon levels. Also, there were regional differences in PCB levels and other chlorinated hydrocarbons.

DISCUSSION The absence of a significant difference in PCB levels between disease groups A and B does not support the hypothesis that PCBs cause immunosuppression in harbour porpoises and increase their chance of dying from an infectious or parasitic disease. It is also in contrast with laboratory studies which have shown that PCBs cause immunosuppression (Vos and Luster, 1989) and increase mortality from viral (Friend and Trainer, 1974; Imanishi *et al.*, 1980; Koller and Thigpen, 1973), bacterial (Smith *et al.*, 1978; Thomas and Hinsdill, 1978), and protozoan diseases (Loose *et al.*, 1978).

There are a number of possible reasons why no link was found between PCB levels and cause of death. For example, it may be that the dose of PCBs to which the porpoises were exposed does not cause immunosuppression. Also, it is possible that a significant difference in PCB levels beween the two groups is masked by the relatively small sample size combined with the potentially large number of confounding factors. For the latter reason it would be useful to carry out a similar study with a large sample size.

In conclusion, we found no significant differences in PCB levels between harbour porpoises that died from an infectious or parasitic disease, and those that died from acute physical trauma. This does not support the hypothesis that PCBs cause immunosuppression in harbour porpoises and increase their risk of dying from an infectious or parasitic disease.

ACKNOWLEDGEMENTS This study was funded in part under contract to the U.K. Department of the Environment as a contribution to its co-ordinated programme of research on the North Sea. We acknowledge H.M. Coastguard, RSPCA, coastal district, county and borough councils, Receivers of Wrecks, Duchy of Cornwall, Fort Victoria Aquarium, Kingdom of the Sea Hunstanton, MAFF Fisheries Laboraory Lowestoft. Sunderland Museum, and numerous individuals for their help in reporting and transporting the carcasses. We thank the staff of the MAFF Veterinary Investigation Centre Polwhele, where the *portmortem* examinations of the harbour porpoises stranded in Cornwall took place. We thank Dr Tony Martin, who organized a *postmortem* session on harbour porpoises at the Sea Mammal Research Unit, Ms Eileen Harris, Department of Zoology, Natural History Museum, London, for the identification of the parasites, Dr Seamus Kennedy, Veterinary Research Laboratories, Stormont, Belfast, for testing for the presence of morbillivirus, and Mr Andrew Cunningham, Institute of Zoology, London, for his support in this project.

REFERENCES

Aguilar, A., and Raga, J.A. 1990. Mortality of dolphins in the Mediterranean Sea. Politica Cientifica, 25: 51-54.

Allchin, C.R., Kelly, C.A., and Portman, J.E. 1989. Methods of analysis for chlorinated hydrocarbons in marine and other samples. Aquatic environment protection: analytical methods, MAFF directorate of fisheries research, Lowestoft, 6, 25 pp.

Anonymous 1961. Standardized methods for measuring and recording data on the smaller cetaceans. J. Mammal., 42: 471-476.

Brouwer, A., Reijnders, P.J.H., and Koeman, J.H. 1989. Polychlorinated biphenyl (PCB)-contaminated fish induces vitamin A and thyroid hormone deficiency in the common seal *(Phoca vitulina).* Aquat. Toxicol., 15: 99-106.

Friend, M. and Trainer, D.O. 1974. Experimental DDT-duck hepatitis virus interaction studies. J. Wildl. Manage., 38: 887-895.

Imanishi, J., Nomura, H., Matsubara, M., Kita, M., Won, S.J., Mizutani, T., and Kishida, T. 1980. Infect. Immun., 29 :275-277.

Koller, L.D. and Thigpen, J.E. 1973. Reduction of antibody to pseudorabies virus in polychlorinated biphenyl-exposed rabbits. Am. J. Vet. Res., 34: 1605-1606.

Kuiken, T. and Baker, J.R. 1991. Guidelines for the postmortem and tissue sampling of cetaceans. Zoological Society of London, London, 16 pp.

Loose, L.D., Silkworth, J.B., Pittman, K.A., Benitz, K.F. and Mueller, W. 1978. Impaired host resistance to endotoxin and malaria in polychlorinated biphenyl- and hexachlorobenzene-treated mice. Infect. Immun., 20: 30-35.

Smith, S.H., Sanders, V.M., Barrett, B.A., Borzellera, J.F., and Munson, A.E. 1978. Immunotoxicological evaluation on mice exposed to polychlorinated biphenyls. Toxicol. Appl. Pharmacol., 45: 330.

Sokal, R.R. and Rohlf, F.J. 1981. *Biometry.* 2nd edition. Freeman, San Francisco. 859pp.

Thomas, P.T., and Hinsdill, R.D. 1978. Effect of polychlorinated biphenyls on the immune responses of Rhesus monkeys and mice. Toxicol. Appl. Pharmacol., 44: 41-51.

Vos, J.G. and Luster, M.I. 1989. Immune alterations. Pp. 295-324. In *Halogenated biphenyls, terphenyls, napthalenes, dibenzodioxins and related products* (Eds. R.D. Kimborough and A.A. Jensen). Elsevier, Amsterdam.

IS ADRENOCORTICAL HYPERPLASIA IN THE HARBOUR PORPOISE (*Phocoena phocoena*) ASSOCIATED WITH CHLORINATED HYDROCARBONS?

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INTRODUCTION From laboratory experiments, it is known that chlorinated hydrocarbons have chronic effects on several species of birds and mammals (Peterle, 1991). These usually include an increase in size, production, or both of the adrenal gland (Wassermann *et al.*, 1973; Copeland and Cranmer, 1974; Lehman *et al.*, 1974; Sanders *et al.*, 1977; Hansen *et al.*, 1979). These adrenal changes may be due to induction of microsomal liver enzymes by chlorinated hydrocarbons leading to an increased metabolism of adrenocortical steroid hormones, especially glucocorticoides of the *zona fasciculata* (Copeland and Cranmer, 1974; Peterle, 1991). Adrenocortical hyperplasia has also been noted in grey seals (*Halichoerus grypus*), ringed seals (*Phoca hispida*), (Bergmann and Olsson, 1985) and in harbour porpoises (*Phocoena phocoena*) (Joiris *et al.*, 1991), and has been associated with chronic exposure to chlorinated hydrocarbons.

Therefore, we decided to examine the adrenal glands of stranded and by-caught harbour porpoises for the presence of changes to the adrenal gland, and to compare these with the concentration of chlorinated hydrocarbons found in their blubber.

MATERIALS AND METHODS We examined the adrenal glands of 28 harbour porpoises that were found stranded on the coast of Great Britain between 1989 and 1991, except for one that was found entangled in a fishing net. A full *postmortem* examination was carried out on each of these animals to establish the cause of death.

After measuring the weight and measurement of each adrenal gland, transverse sections of the right adrenal gland were cut at right angles to the longitudinal axis, and halfway along its length. These were routinely stained with haematoxylin and eosin for light microscopical examination. A one cm square grid was used to estimate the area of cortex, medulla, and stroma in each section. From this and the total volume of the adrenal gland, the volumes of the above-mentioned tissues were calculated.

Because the adrenal gland parameters were significantly correlated with the body length of the carcasses, we used corrected values to be able to compare between animals of different lengths. These are referred to as relative adrenal weight, relative adrenal volume and so on.

Cross-sectional samples of blubber were collected adjacent to the dorsal fin and stored at -20°C until analysis was carried out. The levels of the following contaminants were measured according to Allchin *et al.* (1989): HCB, alpha-HCH, gamma-HCH, p,p'-DDE, p,p'-DDT, p,p'TDE, dieldrin, and 25 individual chlorobiphenyls. The sum of the 25 chlorobiphenyls measured (="total PCBs") and the sum of congeners # 28, # 52, # 101, # 118, # 138, # 153, and # 180 (= "ICES 7 PCBs") was also calculated.

Bivariate product-moment correlation coefficients were calculated between the relative adrenal variables and the parameters that were continuously distributed such as age, body condition, and levels of chlorinated hydrocarbons. One-way analysis of variance was used to test whether differences between the relative adrenal variables were associated with discretely distributed parameters, such as sex, season, and duration of cause of death.

RESULTS AND DISCUSSION The adrenal glands of the harbour porpoises are composed of two different structures: *cortex* and *medulla*, similar to terrestrial mammals. The most distinctive feature was the convoluted nature of the adrenal cortex, due to penetrating septae consisting of fibrous tissue. The cortex was divided into three different zones:
-the outermost *zona glomerulosa*, which secretes mineralocorticoids such as aldosterone;
-the *zona fasciculata,* which is the largest zone, and produces glucocorticoids such as cortisone and corticosterone;
-the innermost *zona reticularis,* which secretes sex hormones.

Based on the pathological diagnosis, the animals were divided into two disease groups, A and B. The porpoises in disease group A (N=11) died due to an acute cause, such as physical trauma or haemorrhage from a stomach ulcer. The porpoises in disease group B (N=14) died due to a chronic cause, such as starvation or a chronic parasite infection.

The relative adrenocortical volume was not significantly correlated with any of the individual chlorinated hydrocarbons measured, ICES 7 PCBs, or total PCBs. This is in contrast to suggestions from a previous study (Joiris *et al.*, 1991), in which the adrenocortical hyperplasia found in two harbour porpoises stranded on the Belgian coast was thought to be associated with toxins such as organochlorines. It is also at variance with the conclusions of Bergmann and Olsson (1985), who suspected that the adrenocortical hyperplasia they found in 11 of 19 grey seals and 6 of 10 ringed seals in the Baltic Sea resulted from organochlorine pollution.

Instead we found a significantly higher relative adrenocortical volume in harbour porpoises that had died from a chronic cause of death (group A) ($F_{1,23}$=13.15, P<0.01). From concentration of nuclei in the cortex, it was determined that this increased voluma was a result of hyperplasia rather than hypertrophy. This indicates that factors associated with a chronic cause of death may have caused adrenocortical hyperplasia in these animals. Similar results have also been found in some terrestrial species, for example rabbits suffering from starvation (Bouillé and Assenmacher, 1970) and sheep infected with stomach parasites (Adams, 1981).

In conclusion, we found no significant correlations between the level of chlorinated hydrocarbons measured and the adrenocortical volume. However, harbour porpoises that died from a chronic cause of death had a significantly higher adrenocortical volume than harbour porpoises that died from an acute cause of death. This suggests that in the former, adrenocortical hyperplasia may have resulted from factors associated with their cause of death rather than chronic exposure to chlorinated hydrocarbons.

ACKNOWLEDGEMENTS This study was funded in part under contract to the UK Department of the Environment as a contribution to its co-ordinated programme of research on the North Sea. We are also grateful for the financial support of Greenpeace UK. We acknowledge the help of the Natural History Museum, H.M. Coastguard, RSPCA coastal district, county and borough councils, Sea Mammal Research Unit, Receivers of Wreck, Duchy of Cornwall, Fort Victoria Aquarium, Kingdom of the Sea Hunstanton, MAFF Fisheries Laboratory Lowestoft, Sunderland Museum, and numerous individuals for their help in reporting and transporting the carcasses. We thank the staff of the MAFF Veterinary

Investigation Centre Polwhele, where the *postmortem* examinations of the harbour porpoises stranded in Cornwall took place, Dr. Tony Martin, who organised a *postmortem* session on harbour porpoises at the Sea Mammal Research Unit, and Ms Linda Boxer for her assistance in the histological processing.

REFERENCES

Adams, D.B. 1981. Changes in blood leucocytes, bone marrow and lymphoid organs in sheep infected with *Haemonchus contortus*. Int. J. Parasitol., 11: 309-317.

Allchin, C.R., Kelly, A. & Portmann, J.E. 1989. Method of analysis for chlorinated hydrocarbons in marine and other samples. Aquat. Environ. Protect.: Analyt. Meth., 6. MAFF Directorate of Fisheries Research, Lowestoft.

Bergman, A. and Olsson, M. 1985. Pathology of Baltic grey seal and ringed seal females with special reference to adrenocortical hyperplasia: Is environmental pollution the cause of a widely distributed syndrome? Finnish Game Res., 44: 47-62.

Bouillé, C. and Assenmacher, I. 1970. Effects of starvation on adrenal cortical function in the rabbit. Endocrinology, 87: 1390-1394.

Copeland, M.F. and Cranmer, M.F. 1974. Effects of *o,p'*-DDT on the adrenal gland and hepatic microsomal enzyme system in the beagle dog. Toxicol. Appl. Pharmacol., 27: 1-10.

Hansen, L.G., Dorn, S..B. and Beamer, P.D. 1979. Residues and effects from feeding high concentrations of hexachlorobenzene to broiler chickens. Poultry Sci., 58: 81-86.

Joiris, C., Bouquegneau, J.M., Borrns, M., Tavrnier, J. and Coignoul, F. 1991. Heavy metals, pathology, and microbiology of two harbour porpoises stranded along the Belgian coast. P. 25. In *European Research on Cetaceans - 5* (Ed. P.G.H. Evans) Proc. 5th Ann. Conf. ECS, Sandefjord, Norway, 21-23 February 1991. European Cetacean Society, Cambridge. 131 pp.

Lehman, J.W., Peterle, T.J. and Mills, C.M. 1974. Effects of DDT on bobwhite quail *(Colinus virgianus)*) adrenal gland, Bull. Environ. Contam. Toxicol., 11: 407-414.

Peterle, T.J. 1991. Chronic effects on organisms. Pp. 157-188. In *Wildlife toxicolocy*. Van Nostrand Reinhold, New York.

Sanders, O.T., Kirkpatrick, R.L. and Scanlon, P.E. 1977. Polychlorinated biphenyls and nutritional restriction: their effects and interactions on endocrine and reproductive characteristics of male white mice. Toxicol. Appl. Pharmacol., 40: 91-98.

Wassermann, D., Wassermann, M., Cucos, S. and Djavaherian, M. 1973. Function of adrenal gland-zona fasciculata in rats receiving polychlorinated biphenyls. Environ. Res., 6: 334-338.

SKIN AS A SUBSTITUTE FOR BLUBBER FOR MONITORING ORGANOCHLORINE COMPOUNDS IN CETACEANS USING BIOPSIES

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Until the mid 1980's, monitoring of organochlorine pollutant levels in cetaceans relied on specimens found stranded on the shore or caught by fisheries. However, in the last few years, sampling of free-ranging cetaceans by means of biopsy darts at a distance has become increasingly used. This is a non-invasive technique which permits obtaining fresh samples from the normal, healthy population.

Some biopsy darts collect both blubber and skin. However, blubber biopsies usually contain the most superficial blubber strata and, because the distribution of organochlorines in the different strata is not homogeneous, the concentrations detected in the superficial layers may not be representative. The aim of the present study was to ascertain the reliability of skin for monitoring organochlorine pollutants in cetaceans and, particularly, to determine how representative is skin of the pollutant load stored in the blubber, the main body compartment for organochlorine storage.

MATERIALS AND METHODS Organochlorine concentration and composition in skin and blubber from twenty striped dolphins (*Stenella coeruleoalba*) sampled in the western Mediterranean Sea were determined. Organochlorine pollutants were analysed, following standard techniques which included an extraction of the lipophilic component of the tissue with n-hexane in a Soxhlet apparatus, clean-up with sulphuric acid, and injection of the purified extract in a Hewlett Packard 5890 gas-chromatograph equipped with an Ni_{63} electron capture detector. To account for variation in lipid richness between the tissues, pollutant concentrations were calculated on the basis of the lipids extracted.

RESULTS AND DISCUSSION Concentrations of tDDT and BCP in the blubber and skin of striped dolphins were highly correlated ($p<0.001$). However, for any given concentration in the blubber, the corresponding values for the skin were about 20% lower, both for tDDT and PCBs. This suggests that skin has a slightly lower capacity than blubber for retaining organochlorines. The reason for this difference is unknown, although a difference in lipid qualitative composition beween the two tissues may account for it.

Figure 1 shows the relative contribution (expressed as a percentage of the total) of the different PCB congeners and the various DDT forms in the blubber and skin of the dolphins. It can be seen that the variation in relative contribution of each compound in the two tissues is negligible, and this indicates that skin is a fairly good indicator of blubber organochlorine composition. However, because of the low lipid content of the skin, organochlorines may be undetectable in animals exposed to low levels of pollution. Thus, assessment of organochlorines in skin samples from North Atlantic fin whales, a population carrying DDT and PCB blubber levels in the range 0.5-1ppm lipid basis, was impracticable because the amount of organochlorines extracted from a skin biopsy were below analytical detection limits.

In conclusion, skin biopsies are considered to be a good method to infer organochlorine residue levels in cetaceans provided that the load of organochlorines carried by the sampled individual is high enough to allow for a correct analytical determination of the pollutants.

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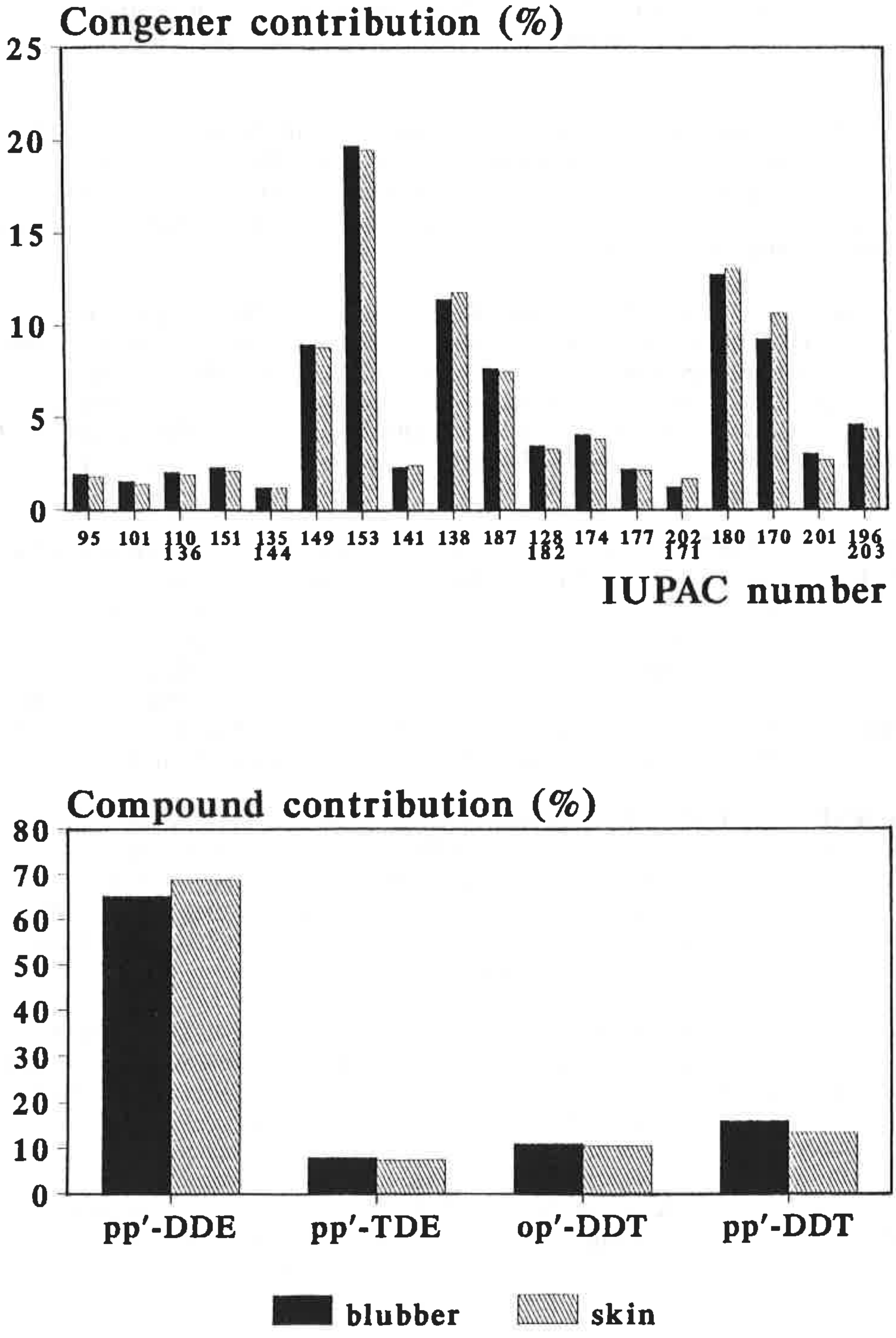

Fig. 1 Relative contribution (expressed as a percentage of the total) of the different PCB congeners and the various DDT forms in the blubber and skin of striped dolphins

PRELIMINARY DATA ON ORGANOCHLORINE POLLUTANTS IN MEDITERRANEAN MONK SEALS

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The Mediterranean monk seal *(Monachus monachus)* is one of the most endangered mammals worldwide. The species was initially distributed throughout the entire Mediterranean Sea, Black Sea, and the adjacent waters of northern Africa and Portugal, but was drastically reduced by direct habitat destruction. Today, the world population of the species is estimated at about 300-400 individuals, with three main areas of concentration: the Greek and Turkish Islands (about 100-150 individuals), the coastline of Mediterranean Morocco and western Algeria (about 20-40 individuals), and the Sahara coast (about 100-150 individuals) (Council of Europe, 1991).

The presence of chemical contaminants such as organochlorine pollutants or heavy metals have been reported frequently in Mediterranean cetaceans. Although Mediterranean monk seals have not been analysed for organochlorine pollutants to date, it has been suggested that exposure to these chemicals might hinder their reproductive capacity (Reijnders and de Vischer, 1988; Anselin *et al.* 1990), as has been found to occur in other seal species.

This report presents the results of preliminary analyses of organochlorine pollutants carried out in some monk seals from the Mediterranean Moroccan and Saharan coast populations.

MATERIALS AND METHODS Blubber or skin samples were collected from one live individual in the Chafarinas Islands (Spain), situated near the Mediterranean coast of Morocco, on 23 February, 1991, and from three carcasses found near La Güera, on the Saharan coast, in December, 1992 (Fig. 1). In all cases, the specimens sampled were considered to be adult. The individual from the Chafarinas Islands was a male, but the sex of the other seals was unknown.

The samples were wrapped in aluminium foil and preserved in a deep freeze until analysis. Organochlorines were determined by extracting the lipophilic phase of the tissues with n-hexane in a Soxhlet apparatus, clean-up with concentrated sulphuric acid, and injection in a capillary chromatograph equipped with an electron capture detector 63 Ni. Quantification of PCBs was performed with a 1260 Arclor standard, calibrated against individual congener standards. The concentrations reported are always expressed on an extractable lipid basis.

RESULTS AND DISCUSSION Table 1 shows the organochlorine levels detected in the samples. The individuals from the Saharan coast gave different levels of contamination, ranging fron 1mg/kg to 250mg/kg of PCB. Part of the difference may be due to differences in age and sex of the individuals sampled. In marine mammals, organochlorine loads tend to increase with age during the juvenile stage, both in males and females, because the uptake of contaminant usually exceeds metabolisation and excretion. In adult males, this pattern continues and their contaminant levels increase with age, although levels often reach a plateau in older individuals. However, in sexually mature females, concentrations often decrease because they transfer appreciable quantities of these compounds to their offspring during pregnancy and, to a larger extent, during lactation (Aguilar, 1987).

The organochlorine level detected in the adult male sampled from the Mediterranean population was at an intermediate level (Table 1). Indeed, the PCB level in the blubber of this animal, as well as the most contaminated specimin from the Sahara (probably an adult male), were found to exceed the threshold from which tumours and pathological stenosis occurred in the uterine horns of northern European seals (Helle*et al.*, 1976; Reijnders, 1980; Baker, 1989). These pathologies led to female reproductive impairment and severe population declines in several seal populations during the 1970s and 1980s. Moreover, PCB levels of this magnitude have been associated with depression of immunocompetence (Brouwer *et al.*, 1989) and alterations in skeletal development (Bergmann *et al.*, 1986;Zakharov *et al.*, 1990) in several species of pinnipeds.

The DDT and PCB levels detected in these specimens suggest that on both the western Mediterranean and the Saharan coasts, the populations may be near a level of pollutant exposure likely to produce negative effects in their capacity for survival. Given the low levels of abundance of the species, this possibility is especially alarming and, therefore, further studies on contaminant levels and effects in monk seals are urgently needed.

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REFERENCES

Aguilar, A. 1987. Using organochlorine pollutants to descriminate marine mammal populations: a review and critique of the methods. Mar. Mamm. Sci., 3(3): 242-262.

Anselin, A., Van Nelst, M., Buedels, R. and Devillers, P. 1990. Analyse descriptive et project pilote preparatoire a une strategie pour la conservation du phoque moine. Rapport EUR 13448 FR-CEE.

Baker, J.R. 1989. Pollution-associated uterine lesions in grey seals from the Liverpool Bay area and the Irish Sea. Vet. Rec., 125: 303.

Bergmann, A., Olsson, M. and Reiland, S. 1986. High frequency of skeletal deformities in skulls of the Baltic grey seal. Int. Counc. Explor. Sea, Doc CM/1986/N:15, 7pp.

Brouwer, A., Reijnders, P.J.H. and Koeman, J.H. 1989. Polychlorinated biphenyl (PCB) - contaminated fish induces vitamin A and thyroid hormone deficiency in the common seal *(Phoca vitulina)*, Aquat. Toxicol., 15: 99-106.

Council of Europe. 1991. Seminar of Conservation of the Mediterranean monk seal. Technical and Scientific aspects. Antalya, Turkey. 1991. Directorate of the Environment. Secretariat Berna Conservation, Estraburg.

Helle, O., Olsson, M. and Jensen, S. 1976. PCB levels correlated with pathological changes in seal uteri. Ambio, 5: 261-263.

Reijnders, P.J.H. 1980. Organochlorine and heavy metal residues in harbour seals from the Wadden Sea and their possible effects on reproduction. Neth. J. Sea Res., 14: 30-65.

Reijnders, P.J.H. and De Vischer, M. 1988. The Mediterranean monk seal. Action Plan. IUCN/UNEP, Athens.

Zakharov, V.M. and Yablokov, A.V. 1990. Skull asymmetry in the Baltic grey seal: effects of environmental pollution. Ambio, 19(5): 266-269.

	W.MEDITERRANEAN	SAHARA COAST		
	MMON 91-1	MMON 92-1	MMON 93-1	MMON 93-2
%lipids	1.98	20.650	1.72	9.37
pp'DDE	19.9	0.310	59.29	4.02
pp'TDE	1.54	0.021	0.39	0.049
op'DDT	1.73	0.028	0.28	0.022
pp'DDT	3.55	0.056	6.74	0.57
tDDT	26.720	0.415	66.700	4.661
PCB congeners:				
95	0.73	0.022	0.38	0.06
101	0.64	0.015	1.83	0.17
110+136	0.35	0.029	3	0.26
151	0.46	0.023	1.59	0.15
135+144	0.31	0.009	0.48	0.05
149	1.96	0.045	6.23	0.57
153	30.4	0.317	65.72	5.29
141	0.82	0.026	1.35	0.11
138	13.58	0.160	36.75	2.88
187	6.74	0.110	18.18	1.64
128+183	4.15	0.044	9.58	0.83
174	1.43	0.030	3.85	0.39
177	1.29	0.021	3.42	0.31
202+171	0.77	0.018	1.51	0.21
180	16.13	0.151	35.52	3.08
170	11.55	0.130	23.24	2.09
201	1.68	0.050	8.05	0.76
196+203	5.58	0.080	14.97	1.32
195	3.73	0.040	4.16	0.4
194	5.00	0.040	4.67	0.42
tPCB	107.300	1.359	244.480	20.990

Table 1, Organochlorine residue levels (expressed as ppm in relation to the extractable lipids) found in the monk seals analysed.

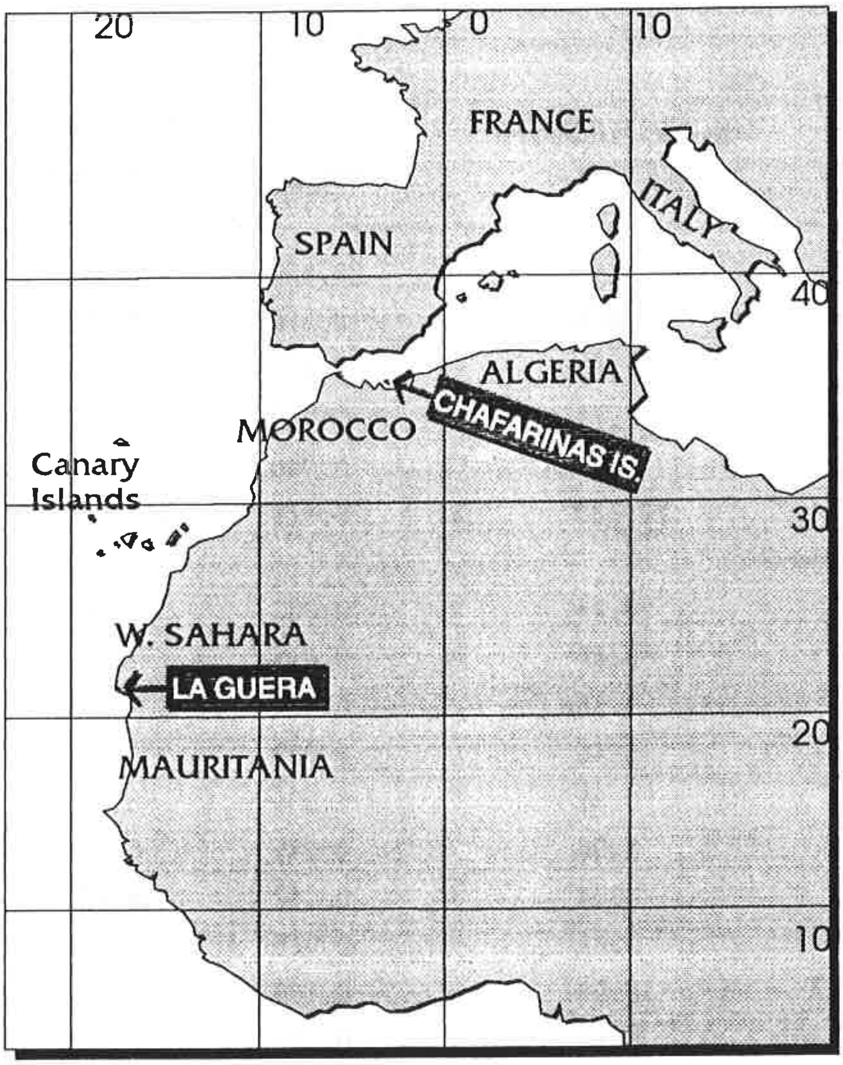

FIG. 1: LOCATIONS WHERE MONK SEAL SAMPLES WERE OBTAINED

INDIVIDUAL VARIATION AND TISSUE DISTRIBUTION OF MERCURY, METHYL MERCURY AND SELENIUM IN THE HARBOUR PORPOISE (*Phocoena phocoena*)

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INTRODUCTION In seals and odontocetes, an atypically low proportion of methylmercury (mHg) in relation to total mercury (tHg) has been found in the liver, kidney and brain compared to its occurrence in the food (Koeman *et al.*, 1973). In the striped dolphin (*Stenella coeruleoalba*), Itano *et al.*, (1984) have shown that total mercury tends to increase with age beyond the time when levels of methyl mercury begin to level off. This points to an age-related demethylation of mercury followed by accumulation of inorganic mercury mainly in the liver, probably as mercuric selenide (HgSe, Tiemananite) (Marloja and Berry, 1980). However, selenium has also been discovered to have a direct protective effect against methyl mercury in the blood (Lourdes *et al.*, 1991) and brain (citations in Itano *et al.*, 1984). If this is the case, one might expect a relationship between selenium and mercury in tissues where mercury demethylation may occur. For the striped dolphin, Itano *et al.*, (1984) have discovered significant correlations between selenium and mercury (not necessarily on a 1:1 molar basis) in a range of tissues including muscle.

The aim of this project was to investigate the changing proportional burden of organomercurials with age and the selective accumulation of mercury in specific tissues of the harbour porpoise (*Phocoena phocoena*). To tie in with that, I intended to investigate whether the reported molar relationship between mercury and selenium (Koeman *et al.*, 1973) is age dependent and whether there is a correlation with the proportional burden of organomercurials.

METHODS Tissue samples from two specimens (an old female, code XT 335/92; and a juvenile male only a few weeks old, code XT 337/92) were obtained from Dr. Thijs Kuiken at the Institute of Zoology, London. Muscle samples from nineteen specimins were obtained from Dr. Christina Lockyer at the Sea Mammal Research Unit, Cambridge. Subsamples were weighed and dried in the oven at 105°C for 48 hours to determine fresh weight/dry weight ratios.

Mercury was analysed by cold vapour generation atomic absorption spectrometry using a Varian AAS 1475 spectrometer and VGA 76 vapour generation accessory.

For determination of organic mercury, a modified Magos method (Magos, 1972) was applied using a mercury monitor Model 1235 (Laboratory Data Control) and Speedomax G recorder supplied by Dr. Magos for an earlier study (Perreira, 1992).

Selenium was analysed by hybride generation atomic absorption spectrometry using the Varian AAS 1475 and VGA 76, according to the method described in Perreira (1992).

RESULTS AND DISCUSSION Levels of selenium, mercury, and proportions of organic mercury, in muscle samples are shown in Table 1.

No strong correlation between mercury levels and age, length or weight was demonstrated (Figs. 1-3). Body length is often used as an approximation of age, but Hinda *et al.* (1982) draw attention to the fact that Hg levels in dolphins are not size dependent within the same age class. For juveniles under one year, the size range in this sample was 72cm to 110cm and for one year olds, it was 94cm to 143cm.

Juvenile animals may have high levels of mercury which led to suggestions that variation in mercury levels may be linked to the specimin's origin on a regional scale. Origin of animals in this study was known but no trend in mercury levels relative to geographical area was discovered. The unknown migratory habits of harbour porpoises would make an interpretation of geographical variation difficult.

Mercury concentrations for a range of tissues from a juvenile male and an old female harbour porpoise are shown in Table 2. By far the highest mercury levels are found in the liver of both specimen. The difference between mercury concentration in the liver and other tissues is especially marked in the older specimen. The difference between mercury concentration in the cerebrum and cerebellum in the older animal is interesting and has also been shown by Itano *et al.* (1984) in the striped dolphin.

The proportional burden of organic mercury for the two specimens supplied by Dr. Kuiken was as follows:

Tissue	**Organic mercury** **XT 335/92**	**XT 337/92**
Cerebrum	6%	70%
Cerebellum	11%	-
Liver	18%	25%
Kidney	48%	41%
Muscle	69%	85%
Spleen	82%	-
Pancreas	-	47%

The observed pattern corresponds to that reported by Itano *et al.* (1984), with a lower proportion of methyl mercury in the tissues of the older specimen. However, the proportion of methyl mercury in the kidney is similar for both specimens. Because of considerable variation in the readings for inorganic mercury for the kidney of the younger animal, the percentage values are based on averages.

There is a significant relationship between the proportion of organic mercury in muscle tissue of harbour porpoise and age (data based on SMRU specimen) with $n=7$, r_S (Spearman's coefficient) $= -0.775$, $t= -2.743$ and $P<0.05$). However, the sample size is small and readings were variable so that any such trend should be subjected to further study before conclusions are drawn. For harbour seals (*Phoca vitulina*), Himeno *et al.* (1989) showed active demethylation of mercury in liver and kidney samples *in vitro* and reported higher proportions of mHg in the tissues of younger animals. If there is an age-related change in the proportion of organomercurials and inorganic mercury, this should show up stronger in tissues such as liver and kidney.

Selenium concentration and Hg/Se ratios for the specimen supplied by Dr. Kuiken are shown in Table 3. A 1:1 molar relationship between selenium and mercury would correspond to a weight ratio of Hg/Se of about 2.7 (Koeman *et al.*, 1973). For the values in table 3, there is a molar surplus of selenium over mercury in the liver and kidney, but a molar surplus of mercury over selenium in the muscle of both animals. Himeno *et al.* (1989) report that a 1:1 molar relationship between mercury and selenium is not present in the liver of young harbour seals but is approached with age. Their animals also tended to have a molar surplus of selenium over mercury.

From the data on the SMRU specimen (Table 1) the conclusion is that there is no relationship between the concentration of selenium and that of mercury in the muscle tissue of the harbour porpoise.

ACKNOWLEDGEMENTS I am especially grateful to Tony Cullen at King's College, without whose patient help this work would not have been possible.

Thanks are due to Dr. Christina Lockyer from the Sea Mammal Research Unit at Cambridge for the generous provision of samples and information, and to Dr. Thijs Kuiken from the Veterinary Science Group at the Institute of Zoology, London, for permitting me to attend two post-mortem examinations in order to take samples and for kindly supplying details of the two animals examined. I am also grateful to Dr. Robin Law from the Ministry of Agriculture, Fisheries and Food Laboratory at Lowestoft for supplying reprints and extensive bibliography through my supervisor Dr. Smith, and finally to Dr. Smith himself for supervision and active interest in the project.

REFERENCES

Himeno, S., Watanabe, C., Hongo, T., Naganuma, A. and Imura, N. 1989. Bull. Env. Contamin. Toxicol. 42: 503-509.

Honda, K., Tatsukawa, R., Miyazaki, R. and Fujiyama, T. 1983. Agric. Biol. Chem. 47: 1219-1228.

Itano, K., Kawai, S., Miyazaki, N., Tatsukawa, R. and Fujiyama, T. 1984. Mercury and selenium levels in striped dolphins caught off the Pacific coast of Japan. Agric. Biol. Chem. 48: 1109-16.

Koeman, J.H., Peeters, W.H.M., Koudstaal-Hol, C.H.M., Tijioe, P.S. and De Goeij, J.J.M. 1973. Nature, London, 245: 385-386.

Lourdes, M.A., Cuvin-Aralar, A. and Furness, R.W. 1991. Ecotox. & Env. Safety, 21: 348-364.

Magos, L. 1971. Analyst, 96: 847-853.

Magos, L. and Clarkson, T.W. 1972. Journal of the AOAC: 966-971.

Martoja, R. and Berry, I.P. 1980. Identification of tiemannite as a probable product of demethylation in cetaceans. A complement to the scheme of the biological cycle of mercury. Vie Milieu, 30: 1-10.

Perreira, C.M.C. 1992. PhD Thesis, University of London.

Table 1 Total mercury concentration (range) in tissues and organs of striped and bottle-nosed dolphins

Specimen	Age (yr)	Fw/Dw ratio	tHg(ppm)±95% c. limits (n=3)	% mHg*	Se (ppm)±95% c. limits (n=3)	Hg/Se ratio (wt)
SMRU 1991/01	5	3.349	2.389 ± 0.978	76 %	0.161 ± 0.003	14.84
SMRU 1991/02	0	-	0.410 ± 0.247	-	0.147 ± 0.013	2.79
SMRU 1991/03	0	4.016	0.541 ± 0.133	-	-	-
SMRU 1991/04	0	-	0.239 ± 0.023	-	-	-
SMRU 1991/05	0	-	0.215 ± 0.051	-	-	-
SMRU 1991/06	8	-	1.561 ± 0.307	65 %	-	-
SMRU 1991/07	1	3.447	0.623 ± 0.059	88 %	-	-
SMRU 1991/08	4	-	0.943 ± 0.114	67 %	0.216 ± 0.030	4.37
SMRU 1991/10	0	4.225	0.226 ± 0.074	-	0.381 ± 0.230	0.59
SMRU 1991/11	0	-	0.702 ± 0.366	-	-	-
SMRU 1991/13	1	3.503	1.853 ± 0.127	-	0.205 ± 0.151	9.04
SMRU 1991/14	2	3.556	0.500 ± 0.148	91 %	0.262 ± 0.014	1.91
SMRU 1991/15	0	4.016	0.548 ± 0.265	-	-	-
SMRU 1991/16	-	3.760	0.339 ± 0.150	-	0.222 ± 0.017	1.53
SMRU 1991/17	1	4.000	0.378 ± 0.030	-	0.156 ± 0.031	2.42
SMRU 1991/18	3	3.691	0.764 ± 0.046	74 %	-	-
SMRU 1991/20	2	4.765	0.796 ± 0.098	92 %	0.365 ± 0.025	2.18
SMRU 1991/21	0	3.281	0.291 ± 0.100		0.344 ± 0.050	0.85

*Large variation between readings, percentage based on averages without confidence limits

Table 2 Mercury levels for Xt 335/92 (an old female) and Xt 336/92 (a young male, just a few weeks old). Confidence limits as in Table 1

Specimen:	**XT 335/92**			**XT 337/92**		
Tissue	**n**	**Fw/Dw ratio**	**Hg ($\mu g\ g^{-1}$) & 95% c.l.**	**n**	**Fw/Dw ratio**	**Hg ($\mu g\ g^{-1}$) & 95% c.l.**
First stomach	5	3.454	1.328±0.256	5	4.736	0.794±0.170
Second stomach	5	5.193	0.707±0.114	5	4.922	0.376±0.027
Small intestine	5	5.000	0.768±0.068	5	5.200	0.302±0.017
Spleen	4	5.174	2.949±0.645	2	-	av. 0.222
Heart	3	4.159	1.472±0.409	5	4.095	0.407±0.006
Pancreas	4	4.753	5.467±1.274	5	4.615	0.359±0.009
Blood	5	-	0.580±0.015	5	-	0.208±0.023
Cerebellum	5	5.455	1.352±0.408	-	-	-
Cerebrum	5	4.516	4.325±0.615	5	-	0.328±0.008
Kidney	4	4.570	2.689±0.357	5	4.279	0.632±0.069
Liver	5	3.709	86.240±5.154	5	3.750	1.737±0.611
Muscle	5	3.590	1.524±0.083	5	4.295	0.701±0.089
Lung	5	4.578	1.058±0.197	5	4.473	0.221±0.021
Blubber	5	1.061	0.637±0.300	5	1.423	0.093±0.055
Diaphragm	-	-	-	5	4.714	0.614±0.030
Thymus	-	-	-	4	-	0.251±0.030
Thyroid	-	-	-	3	-	0.471±0.251

Table 3 Selenium and Hg/Se ratios for the specimen supplied by Dr. Kuiken. Confidence limits and n as in Table 1

Specimen:	**XT 335/92**			**XT 337/92**		
Tissue	**n**	**Hg/Se ratio**	**Se ($\mu g\ g^{-1}$) & 95% c.l.**	**n**	**Hg/Se ratio**	**Se ($\mu g\ g^{-1}$) & 95% c.l.**
Kidney	3	1.148	2.342 ±0.259	3	1.401	0.451±0.059
Liver	3	1.787	49.950±9.142	3	1.605	1.082±0.155
Muscle	3	12.290	0.124±0.032	3	6.315	0.111±0.100

Table 3. Selenium and Hg/Se ratios for the specimen supplied by Dr. Kuiken. Confidence limits and n as in table 1.

MERCURY SELENIDE ACCUMULATION IN DOLPHINS

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INTRODUCTION Studies on mercury (Hg) in delphinids in the last twenty years suggest that these animals are the strongest accumulators of mercury on earth (Koeman *et al.*, 1973, Itano *et al.*, 1984, Leonzio *et al.*, 1992). This can be accounted for by the following of ecological and adaptative features of dolphins: (a) a terminal position in the marine trophic network; (b) a long lifespan, up to 40 years; (c) poor Hg excretion ability .

The physiology of these animals must have provided a series of adaptations in the course of the evolution against the toxicity of mercury to cope with high mercury body burden. The complexation of mercury with selenium forming unsoluble mercury selenide is believed to play an important role in Hg detoxication (Martoja & Viale, 1977: Martoja & Berry, 1980; Leonzio & Nigro, 1992). However, the mechanism involved in the production of HgSe granules is still unknown.

The present investigation concerns two aspects of the mercury-dolphin relationship, namely: (1) the quantification of exposure on the basis of their ecological features; and (2) the identification of the cell types involved in HgSe storage and the interactions between mercury selenide and cell structures.

MATERIALS AND METHODS Specimens of different organs were collected from striped (*Stenella coeruleoalba*) and bottle-nosed dolphins (*Tursiops truncatus*) stranded along the Tyrrhenian, Ionian and Adriatic coasts in the last five years. Determination of Hg and Se concentration in organs were performed according to Leonzio *et al.* (1992).

For transmission electron microscopy specimens were chemically fixed and embedded in epoxy resin. Post-fixation and staining procedures were omitted for energy dispersive X-ray microprobe analysis.

RESULTS AND DISCUSSION Mercury and selenium levels in specimens of striped and bottle nosed-dolphins are presented in Table 1. Concentrations in dolphins are compared with those measured in predatory pelagic fishes, such as tuna and sword fishes, and in their typical prey (Table 2). From this comparison it can be seen that: (1) the range of concentrations in dolphins is up to two orders of magnitude higher than those of top fish predators which ccupy the same trophic position; and (2) the relative biomagnification factor, with respect to the levels of mercury in the diet, is much higher for dolphins (c. 500) than for fishes (c. 30).

Assuming the mean daily food assumption of an adult striped dolphin is approximately 3 kg of fishes and cephalopods with an average mercury concentration of 0.3 mg/kg fresh weight (Bargagli *et al.*, 1990), the mean dietary mercury intake for an adult specimen can be roughly calculated at 0.9 mg Hg /day. Moreover, the theoretical mercury intake over the entire lifespan has been calculated and compared with the real dolphin body burden. Real and theoretical trends are comparable at least in the central part of the life-span (Fig. 1). This evidence confirms that the capacity for excretion of mercury by dolphins is very low and consequently that most of the mercury assumed with the diet remains in the tissues in a detoxified form.

The storage of mercury in the form of HgSe granules has been previously reported in the connective of portal vessels of the liver in delphinids (Martoja and Viale 1977; Martoja and

Berry, 1980). In the present investigation, electron dense granules with an x-ray spectrum typical of mercury selenide (Fig. 3), have been also observed within liver macrophages (known as Kuppfer cells) which lines the lumen of synusoidal capillary (Fig. 2). HgSe granules, composed of 150 ≈ particles (Fig. 4), are usually associated with large lysosomal bodies often containing residues of phagocytosed red cells (Fig. 5). This finding is consistent with the evidence, from cell culture, that phagocytic cells can perform alkyl mercury degradation (Suda *et al.*, 1992). Taking into account the fact that red blood cells are well known as vectors for methyl mercury in the body, it can be hypothesised that the phagocytosis of red cells by macrophages represent an important route in methyl mercury detoxication and HgSe production in dolphins. HgSe granules, similar to those observed in Kuppfer cells, were also observed in the spleen and in the lungs, although at a much lower concentration (Fig. 6) In addition, very small mercury selenide granules occur in the brain and in the muscle. These findings demonstrate that the biosynthesis and storage of mercury selenide, although mainly associated with the liver, is not exclusive of this organ.

REFERENCES

Baldi, F. 1984. The biogeochemical cycle of mercury in the Mediterranean Sea. FAO Fishery Report No. 325, Suppl.: 29-43.

Bargagli, R., Leonzio, C., Mattei, N. and Maramai, A. 1990. La biomagnificazione del mercurio nelle catene alimentari pelagiche bentoniche del Mar Tirreno. Oebalia, 16 (suppl.): 583-585.

Koeman, J.H., Peeters, W.H.M., Koudstaal-Hol, C.H.M., Tijoe, P.S. and De Goeij, J.J.M. 1973. Mercury-selenium correlation in marine mammals. Nature, Lond., 245: 385-386.

Itano, K., Kawai, S., Miyazaki, N., Tatzukawa, R. and Fujiyama, T. 1984. Mercury and selenium levels in striped dolphins caught off the Pacific coast of Japan. Agric. Biol. Chem., 48(5): 1109-1116.

Leonzio, C., Focardi, S. and Fossi, C. 1992. Heavy metals and selenium in stranded dolphins of the Northern Tyrrhenian (NW Mediterranean). Sci. Total Environ., 119: 77-84.

Leonzio, C. and Nigro, M. 1992. Modalità di accumulo di mercurio e selenio nei delfinidi. Proceedings 5° Congresso Nazionale Soc. It. Ecol.

Martoja, R, and Viale, D. 1977. Accumulation de granules de sélèniure mercurique dans le fois d'Odontocétes (Mammifères, Cétacés): un mècanisme possible de détoxication du méthylmercure par le sélénium. C.r. hebd. Séanc. Acad. Sci. Paris, D, 285: 109-112.

Martoja, R, and Berry, J.P. 1980. Identification of tiemannite as a probable product of demethylation of mercury by selenium in cetaceans. A complement to the scheme of the biological cycle of mercury. Vie Milieu, 30(1): 7-10.

Nigro, M., Cognetti Alfinito, G. and Menichini, R. 1992. Formazione di complessi tra selenio ed alcuni metalli tossici in organismi marini. Proceedings. 54° Congresso Unione Zoologica. Italiana: 302-303.

Suda, I., Totoki, S.,. Uchida, T. and Takahashi, H., 1992. Degradation of methyl and ethyl mercury into inorganic mercury by various phagocytic cells. Arch. Toxicol., 66: 40-44.

		muscle	*brain*	*kidney*	*liver*
S. coeruleoalba	Hg*	6-168	4-55	5- 204	12-4400
	Se*	5- 55	5-36	25-100	2- 960
T. truncatus	Hg*	5-292	1-5	7-882	12-13100
	Se*	4- 48	3-5	20-190	2- 2400

* µg/g d.w. (min-MAX)

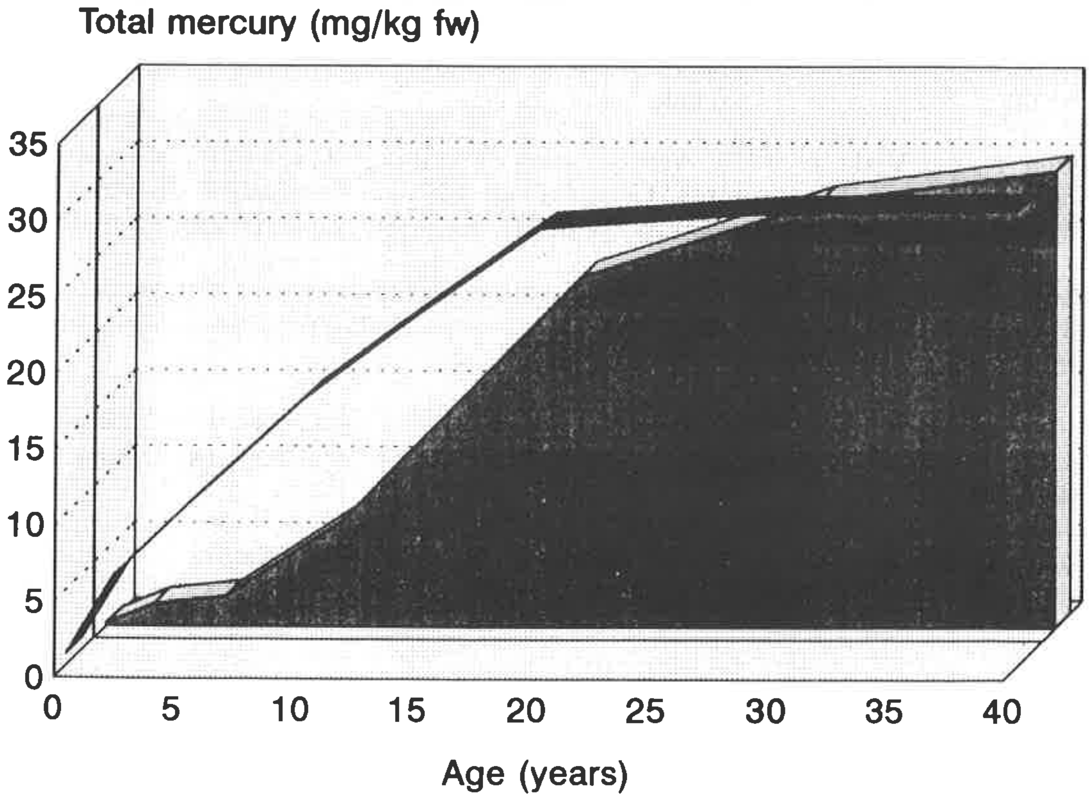
TABLE 1. Total mercury concentration (range) in tissues and organs of Striped and Bottlenosed Dolphin

trophic level	organism	total mercury (mg/kg dw)
primary consumers *	zooplancton	0.02 - 0.1
secondary **	sardine, anchovy	0.10 - 2.0
tertiary **	tuna, swordfish	1.0 - 20 .0

* whole ** muscle

TABLE 2. Total mercury concentration (range) in the pelagic food web of the Tyrrhenian Sea (from Baldi, 1984)

FIGURE 1. Real (area) and theorethical (strip) accumulation of total mercury in the muscle of Pacific Striped dolphin (data re-elaborated from Itano et al., 1984)



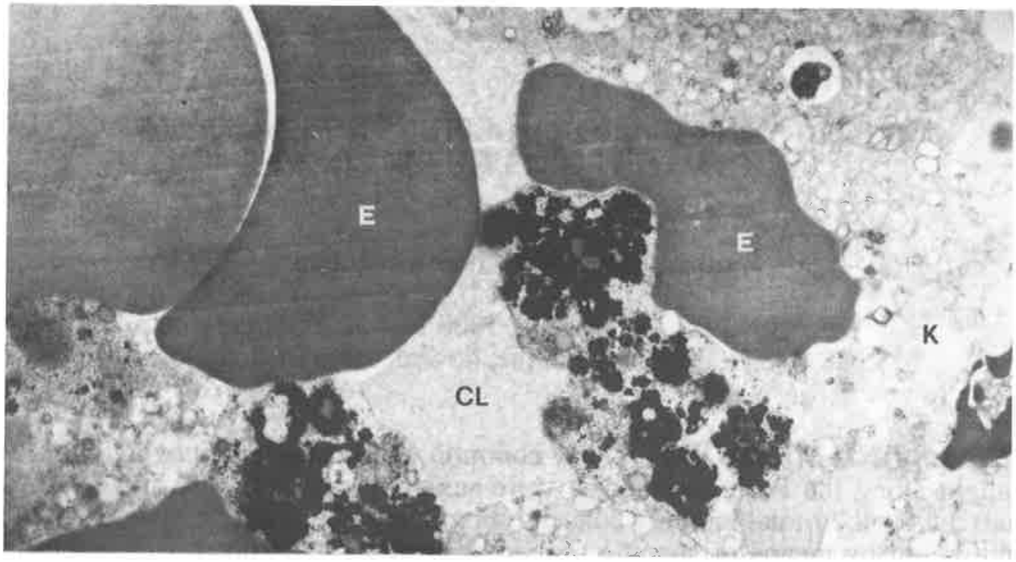


Fig.2 Electron micrograph of a synusoidal capillary showing a Kuppfer cell (K) containing HgSe granules (G). E = erythrocithes, C L = capillary lumen X9000.

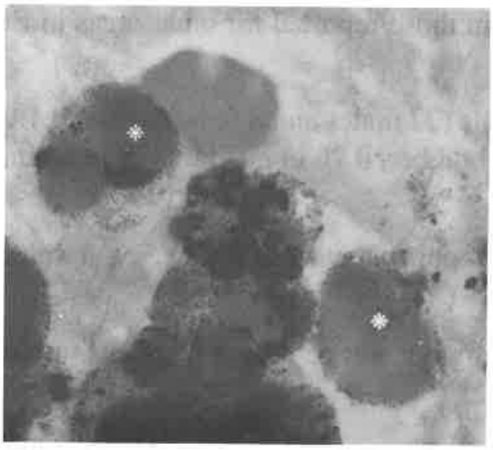


Fig.3 Electron micrograph of a Kuppfer cell showing HgSe granules associated with red cell fragments (*) X11000.

Fig.4 High magnification of a mercury selenide granule showing spherical particles 150 Å in diameter X130000.

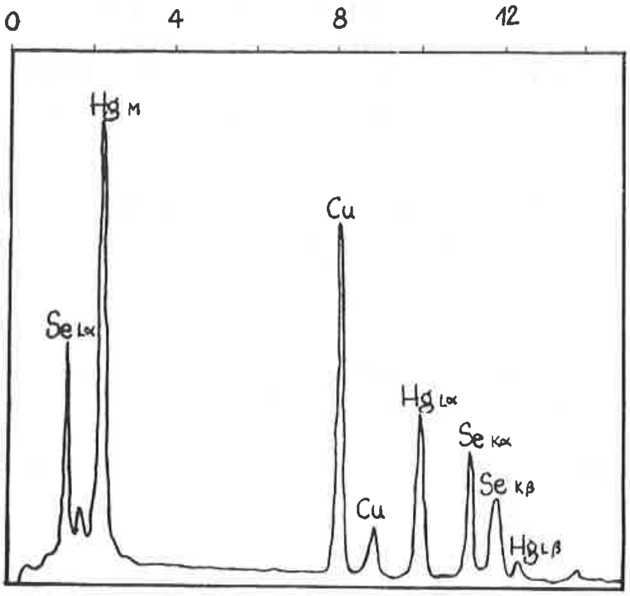


Fig.5 X-Ray spectrum of HgSe granules(Cu peaks are derived from the grid).

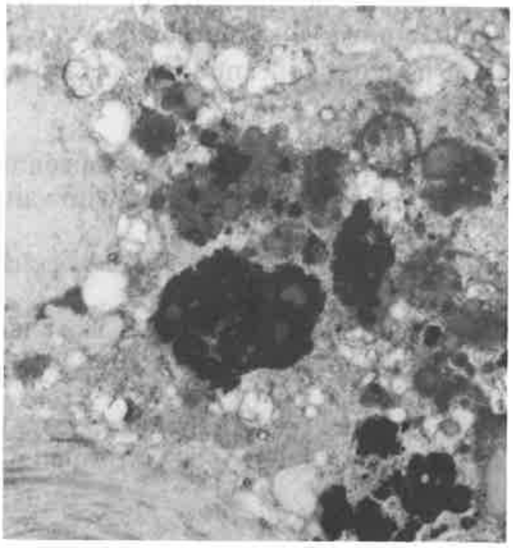


Fig.6 Electron micrograph of the spleen showing HgSe granules X10000.

MERCURY IN COMMON DOLPHINS *Delphinus delphinus* OFF THE PORTUGUESE COAST

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MATERIALS AND METHODS Thirty common dolphins (*Delphinus delphis*) stranded or by-caught along the Portuguese coast were sampled between 1990 and 1992. Samples were analysed for their total mercury concentration in muscle, liver, blubber, kidney, gonads, brain and melon by means of specific atomic absorption spectrometry on a Perkin-Elmer Coleman Mas-50 Mercury Analyzer, after mineralisation (Lawson and Kirkwood, 1980).

RESULTS AND DISCUSSION No geographical differences were observed in the total Hg contamination of common dolphins studied on the Portuguese coast. Basically, the overall contamination levels found were lower than those reported for other areas in Europe (Table 1).

Average total Hg concentrations from 30 individuals (22 males and 8 females) were: 1.00 mg kg^{-1} fresh weight in liver, 0.41 in muscle, 0.33 in blubber, 0.26 in melon, 0.18 in brain, 0.11 in gonads and 0.11 in kidney (Fig. 1, Table 2).

Liver/muscle total Hg concentration ratios were approximately 2:3 (Fig. 2), a value that suggests the possible storage of mercury mainly in liver.

No correlation of increasing total Hg with body length could be detected either in muscle or in liver of adult animals.

Residue concentrations were slightly higher in female than in male gonads (Mann-Whitney U test = 22.0; $p<0.05$; $n_{males} = 19$; $n_{females} = 7$).

In accordance with André *et al.* (1991), the trophic route via cumulative Hg transfers through the marine trophic network can be considered as the major contamination route in marine mammals. The common dolphin has an opportunistic feeding behaviour, apparently reflecting variations in prey availability. Its diet may include different species of fish and cephalopods, but along the Portuguese coast, sardines *Sardina pilchardus* are believed to be its main prey. This is probably the explanation for the comparatively lower levels detected, since mercury concentrations in sardines or the Portuguese coast are very low (0.05 mg kg^{-1} wet weight).

CONCLUSIONS Total Hg concentrations in adult common dolphins from the Portuguese coast are low when compared with values found in other European areas.

Higher Hg concentrations were detected in female than in male gonads.

No variations were detected associated with the geographical origin of the Portuguese specimen nor was there any correlation between increasing total Hg and body length.

Since mercury contamination appears to be higher in older animals, age determination of the specimens studied will be performed in future work.

SUMMARY Total Hg determinations were carried out on 22 males and 8 females of common dolphin found dead (stranded or bycaught) on the Portuguese coast, between 1990 and 1992,

Concentration levels of total Hg on several organs and tissues (muscle, liver, blubber, kidney, gonads, brain and melon) and their variations with growth and sex were investigated. All results are expressed on a wet weight basis.

Total Hg levels ranged from 0.30 to 0.56 ppm (average 0.41) in muscle tissue and from 0.64 to 1.26 ppm (average 1.00) in liver tissue. Liver is the most important accumulating organ in the specimens studied. Kidney levels were low and almost constant (0.11 ppm). Gonad and brain levels were higher in females than on males.

The concentrations found in the tissues analysed seem lower than those reported in the literature for other European areas and may be summarised by the following sequence:

Liver >> Muscle, Blubber > Melon > Brain, Gonad, Kidney

REFERENCES

André, J.M., Boudou, A. and Ribeyre, F. 1991. Mercury accumulation in Delphinidae. Water, Air and Soil Pollution, 56: 187-201.

Joiris, C.R., Holsbeek, L., Bouquegneau, J.M. and Bossicart, M. 1991. Mercury contamination of the harbour porpoise *Phocoena phocoena* and other cetaceans from the North Sea and the Kattegat. Water, Oil and Soil pollution, 56: 283-293.

Lawson, D.A. and Kirkwood, D.S. 1980. An automated method for the determination of total mercury in environmental samples. ICES Doc. CM 1980/E:29.

Martoja, R. and Viale, D. 1977. Accumulation de granules de séléniure mercurique dans la foie d'Odontocètes (Mammifères, Cétacés): un méchanisme possible de détoxication du méthylmercure par le sélénium. C.R. Acad. Sc. Paris, t.285, série D: 109-112.

Thibaud, Y. and Duguy, R. 1973. Teneur de mercure chez les cétacés des côtes de France. ICES, CM 1973/N:2: 8p.

Table 1 Comparisons between mercury concentrations in muscle and liver from specimens off the Portuguese coast with others from different European coasts

Nr. of animals	Area	Sex	Length (cm) mean (min-max)	Hg-T Muscle (mg Kg^{-1} w.w.) mean (min-max)	Hg-T Liver (mg Kg^{-1} w.w.) mean (min-max)	Author
22	Portuguese coast	M	168.5 (96.5-213.0)	0.41 (0.30-0.56)	0.99 (0.64-1.26)	This work
8	Portuguese coast	F	170.1 (125.0-210.5)	0.43 (0.35-0.51)	1.05 (0.81-1.20)	This work
4	Atlantic French coast	F	(124-212)	(0.60-6.24)	(0.89-4.85)	Thibaud and Duguy, 1973
1	Atlantic French coast	M	186	1.84	20.2	Thibaud and Duguy, 1973
1	Belgian coast	M	205.0	5.70	30.0	Joiris *et al.*, 1991
1	Mediterranean	M	205.0	1.46	604.0	Martoja and Viale, 1977

Table 2 Total mercury concentration (range) in the pelagic food web of the Tyrrhenian Sea (from Baldi, 1984)

	Nr. of animals	Length (cm) mean (min-max) sd	Liver mean (min-max) sd	Muscle mean (min-max) sd	Blubber mean (min-max) sd	Melon mean (min-max) sd	Brain mean (min-max) sd	Gonads mean (min-max) sd	Kidney mean (min-max) sd
Total	30	168.9 (96.5-213.0) 29.10	1.00 (0.64-1.26) 00.15	0.41 (0.30-0.56) 0.07	0.33 (0.20-0.59) 0.10	0.26 (0.19-0.40) 0.07	0.18 (0.10-0.39) 0.08	0.11 (0.03-0.24) 0.06	0.11 (0.10-0.13) 0.01
Males	22	168.5 (96.5-213.0) 29.7	0.99 (0.64-1.26) 0.16	0.41 (0.30-0.56) 0.07	0.31 (0.20-0.48) 0.08	0.26 (0.19-0.39) 0.06	0.16 (0.10-0.22) 0.04	0.09 (0.03-0.23) 0.04	0.11 (0.10-0.13) 0.01
Females	8	170.1 (125.0-210.5) 29.3	1.05 (0.81-1.20) 0.13	0.43 (0.35-0.51) 0.05	0.36 (0.25-0.59) 0.12	0.26 (0.19-0.40) 0.08	0.27 (0.15-0.39) 0.12	0.16 (0.08-0.24) 0.06	0.10 (0.10-0.11) 0.01

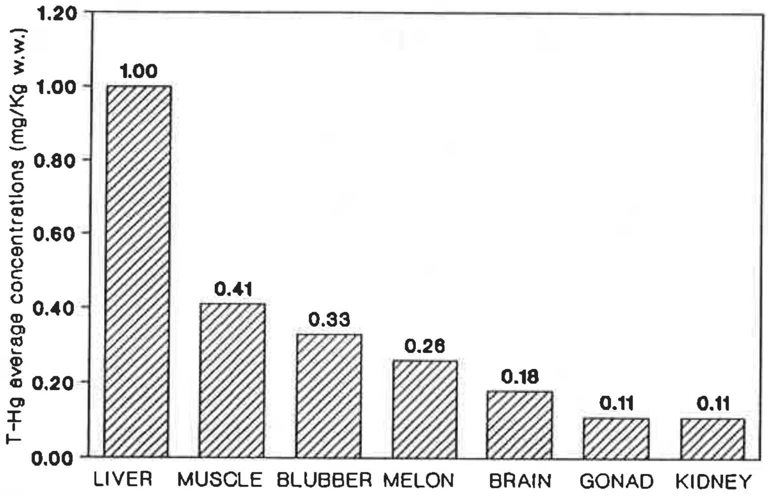

Fig. 1 - Average mercury concentrations (mg T-Hg / Kg w.w.) in different tissues of the common dolphin.

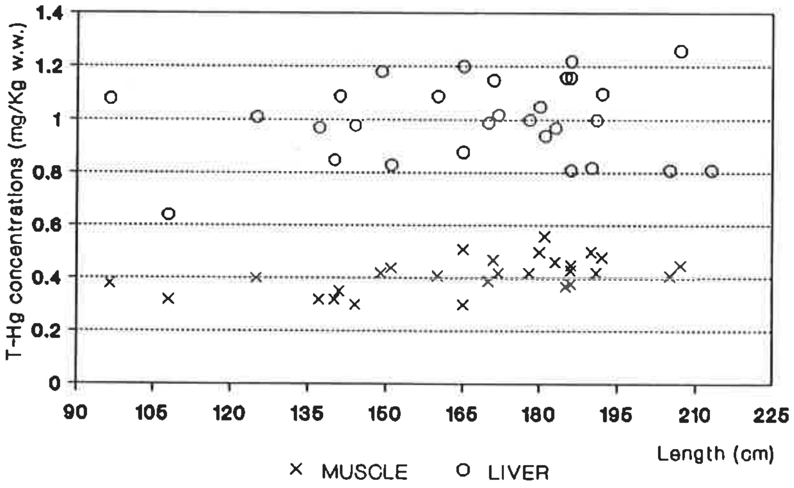

Fig. 2 - Mercury residues (mg T-hg / Kg w.w.) in muscle and liver of the common dolphins.

ARE MAN AND DOLPHIN COMPETING FOR THE SAME RESOURCES IN THE MEDITERRANEAN? -- EVALUATION OF FISH STOCKS THROUGH ELECTRO-ACOUSTIC SURVEYS AND STUDIES ON HUMAN FISHING TECHNIQUES AND DELPHINID HUNTING BEHAVIOUR

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Since 1988, we have been conducting echosounder surveys in the Mediterranean in order to determine the absolute biomass of pelagic fish populations together with their spatial distribution and school structure. Simultaneously we have recorded data regarding the presence of various species of dolphins encountered during the survey. This has allowed to reveal a relationship beween the type of aggregation within the schools and the species of dolphins sighted.

Where there has been evidence of very compact schools of blue fish (mainly clupeids) the visual sightings have typically involved the species bottle-nosed dolphin (*Tursiops truncatus*); on the other hand we have spotted the genus *Stenella* where the echosounder revealed a more dispersed type of fish aggregation. Geographically this difference is represented in the Adriatic and the Tyrrhenian sea respectively.

The most relevant fishing methods employed in the Mediterranean are effectively based on the tendency of certain species to form compact schools. Thus it is reasonable to assume that there would be more competition between fishermen and *Tursiops* than with *Stenella.* If this is true, then can the extent of exploitation of the stocks damage the ecology of those cetaceans more closely competing with man? This is the object of present and future studies we are conducting.

INCIDENTAL CATCHES OF CETACEANS BY THE FRENCH ALBACORE TUNA GILLNET FISHERY

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In February 1992, the European Council banned the use of drift nets longer than 2.5 kilometres in community fleets. A derogation was granted to vessels that have fished for albacore tuna with drift nets in the North East Atlantic ocean during at least two seasons. The act allows vessels to use gillnets up to five kilometres of length, and shall expire on 31 December 1993, *unless the Council decides (...) to extend it in the light of scientific evidence showing the absence of any ecological risk linked thereto.* As a consequence of this, IFREMER has been asked by the French Ministry of the Sea, to collect all available data related to the impact of the French albacore tuna gillnet fishery. A study group of European scientists decided that it would only be possible to assess the impact at the population level of cetaceans. Although there are other non-target species, cetaceans have been chosen because of their status of knowledge, position in the marine environment and public importance. The upper limit of the cetacean incidental catches confidence interval will be estimated using data collected by observers on board the tuna gillnetters during the two years, and the lower limit of the estimated population size confidence interval will be estimated using data collected during a dedicated sighting survey. The ratio of both estimates will provide a "worst case" estimate of the proportions of cetaceans removed from the population.

In summer 1992, eighteen observers monitored 33% of the derogative fleet. They were asked to count and sample all by-catches and incidental catches. Whenever possible, an autopsy was performed on the cetacean and the following samples were collected: teeth, gonads, skin, stomach, and eventually parasites. The observers reported that:

- no turtles were killed by the fishery, and less than ten birds were reported as incidental catch.
- incidental catches of cetaceans represent 0.17% of the overall catch of the albacore tuna gillnetters in terms of number of individuals.
- cetaceans are captured incidentally during the entire season (May-September), but the number of incidental catches per fishing operation is greater in August and September.
- the average rate of incidental catch of cetaceans per kilometre of gillnet is 0.11 (compare with the interval of 0.06 to 0.12 calculated by L. Antoine (IFREMER) for the period 1989-1991).
- the principal cetaceans involved in the catch are striped dolphins (*Stenella coeruleoalba*) and common dolphins (*Delphinus delphis*), comprising 69% and 24% respectively of the total incidental catches of cetaceans.
- for these two species, juveniles represent almost half of the incidental catches.
- 83% of the dolphins (striped and common) observed at sea and identified by the observers were common dolphins.

A similar program will be conducted in 1993. A sighting survey will also be conducted on a vessel specially chartered using line transect sampling methodology and experienced observers. The sighting survey data will be analysed with the program DISTANCE in collaboration with P. Hammond (SMRU, Cambridge).

INSHORE FISHERIES AND MARINE FAUNA ENTANGLEMENT AROUND WALES

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Important concentrations of marine birds and mammals occur throughout the year in the coastal waters around Wales. Where fisheries activity coincides with these concentrations, there is potential for conflict between fishermen and conservationists. This is especially so in areas where static netting gear is used.

In Cardigan Bay, the largest bay in the United Kingdom, both gill nets and tangle nets are used. Bottle-nosed dolphin (*Tursiops truncatus*) , harbour porpoise (*Phocoena phocoena*), grey seal (*Halichoerus grypus*) and thousands of breeding and migrant seabirds are all found close to the most popular netting sites.

Observations to date have not suggested enough seabirds and seals are killed by entanglement in nets to threaten their populations in Wales (Thomas, 1992). However, concern may be warranted over the entanglement of harbour porpoise in tangle nets. Between June 1991 and September 1992, it is known that, in Wales, at least twelve porpoises died through entanglement. Seven of these deaths occurred in Cardigan Bay.

Tangle nets of 10"-12" monofilament mesh are used in Wales to take demersal fish such as thornback rays (*Raja clavatta*) and skate (*Raja batis*). Much of the catch is sent to France and Spain. In a few rocky localities with fast tidal flows, the nets are used to take crayfish (*Palinurus vulgaris*) The sandy bottomed areas off the Dyfi estuary, in Tremadog Bay, and along the Ceredigion coast are favoured tangle netting regions. All are important for marine birds and mammals (Thomas, *in prep.*)

Relatively little is known about the numbers of harbour porpoise using the waters around Wales. In Cardigan Bay, animals are regularly seen in the tidal overfalls at Strumble Head, in the area off Aberporth, to the west of Sarn Cynfelyn, and passing near Ynys Enlli. Here they mainly appear in late summer and autumn (Jones and Okines, 1990; Morgan-Jenks, 1993).

Attempting to calculate the actual number of marine mammals entangled in fishing gear is very much dependent on co-operation from fishermen. They should be encouraged to land by-catches as post-mortem results may be of high scientific value. Observations recorded in a boat's fishing log may give invaluable information as to the distribution of cetaceans and other marine wildlife. Criticism of fishermen may only exaggerate any existing ill feeling between themselves and the conservation lobby.

The different types of static net vary in the threat they pose. Gill nets set below auk breeding cliffs, or anywhere that high densities of birds and mammals are found at sea, will pose serious threat. Nets set in the inter-tidal zone of a sandy beach, on the evidence gathered at Borth and Pembrey, may not be a great threat. Thousands of wintering seaduck appear within 1km of these popular netting sites, yet few get entangled.

Poorly set gill nets and tangle nets are more likely to cause problems than professionally fished gear. Examples of this occurred in the southern part of Cardigan Bay during September 1992. Tangle nets belonging to a Cardigan boat were left out in poor weather conditions near Aberporth and claimed a harbour porpoise; a gill net left out too long at Trevine took a shag (*Phalacrocorax aristotelis*).

The importance of wildlife concentrations and the strength of conservtion interests in Wales calls for the sensitive management of coastal fisheries and a co-operative relationship between interested parties.

Under the Sea Fisheries (Wildlife Conservation) Act 1992, ministers and Sea Fisheries Committees are required to have regard to the conservation of marine flora and fauna in carrying out sea fisheries functions. The UK Government is now required to "achieve a reasonable balance" between conservation and other responsibilities, most notably the need to conserve stocks and the need to protect the interests of the fishing industry. Thus any new byelaws passed to preserve fish stocks must also take into consideration locally important concentrations of marine wildlife.

Dealing with entanglement issues is not as straightforward as it may at first seem. Many variables, such as weather, tide, netting effort and wildlife feeding areas, will play a part in the amount of by-catch taken.

There is, however, a baseline. Any type of fishing gear put in the water, be it lobster pot, trawl or fixed net, will, at some point, take an unwanted by-catch. The occurrence of cetaceans, birds, and other marine fauna in fishing gear is inevitable. It is for conservationists and fishermen to work together to determine at what level it becomes unacceptable.

REFERENCES

Jones, P.H. and Okines, D. 1990. Records of Cetaceans off Bardsey, 1975-1989. In *Report of Bardsey Bird and Field Observatory* , 33: 57-60.

Morgan-Jenks, M. 1993. Cetacean Monitoring on Enlli. Unpublished report.

Thomas, D. 1992. *Marine Wildlife and Net Fisheries Around Wales.* RSPB/CCW, Newtown, Powys. 55 pp.

Thomas, D. 1993. *Marine Wildlife and Fisheries in Cardigan Bay.* RSPB/CCW, Newtown, Powys. 40 pp.

DETERRING DOLPHINS FROM FISHING NETS:
TAKING PASSIVE ACOUSTIC REFLECTORS TO SEA.

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INTRODUCTION Experimental acoustic reflectors, designed to deter small cetaceans from colliding with passive fishing nets, have been tested in controlled inshore trials with wild bottle-nosed dolphins (*Tursiops truncatus*) and shown to be detectable by echo-locating animals at ranges between 50m and 170m. Barriers of reflectors, deployed to simulate a surface set gill-net, appear to induce avoidance behaviour at safe distances, (Mayo and Goodson, 1992; Klinowska *et al.*, 1992; Goodson *et al.*, 1992). Translating this technology into an effective commercial fishing net modification introduces additional parameters that need careful consideration. A short sea trial off the Cornish coast was undertaken in June 1992 with the support of the Seafish Industry Authority (Hull) on board a UK gill-netter (Britannia V), and a short experimental net was studied while being shot and hauled, (Swarbrick, 1992). The exercise set out to examine the physical handling problems that the addition of acoustic reflectors may cause. This sea trial provided an opportunity to examine both modified and unmodified net panels of ‘tuna’ (168mm stretched mesh, red nylon multifilament) gill-netting with a 100 kHz high resolution towed sidescan sonar possessing broadly similar resolving power to that of a dolphin sonar. This paper summarises conclusions from the recent UK studies and attempts to further illustrate the problems of fishing net perception for the smaller cetaceans.

GILL-NET TRIAL The prototype devices employed in this short Cornish sea trial (small ellipsoid shaped pressure release reflectors), were applied to two of four panels of an experimental 240m long ‘tuna’ drift net and were distributed in a 2 x 3m grid pattern across the face of the net. The study included the use of a Waverley 3000 towed sidescan sonar to examine the effectiveness of the modified net as an acoustic barrier. The sidescan sonar equipment, operated at 100 kHz, i.e. with a wavelength (λ) of 15mm in seawater. At this frequency the sonar has a broadly similar resolution to that of the bottle-nosed dolphin. The animal’s resolution is limited by the highest frequency response in its audiogram, i.e. for the bottle-nosed dolphin around 120 to 130 kHz, (Johnson, 1966) and by the presence of these frequencies as spectral components within its sonar transmissions, (Au, 1980). The sidescan sonar operated at a Source Level of 227 dB re 1 μPa which is very close to the maximum SL reported for a bottle-nosed dolphin (Au, 1980). However, it is important to appreciate that the dolphin’s sonar functions as a forward looking (10^o) spot-light system whereas the sidescan generates two very narrow vertical ‘fan’ beams (1.5^o x 50^o) which are projected at 90^o to each side of its track. The sidescan image is built up on a paper record from successive transmissions as the towfish, several metres below the surface, follows its parent vessel’s course.

PASSIVE ACOUSTIC REFLECTORS Whilst an efficient reflector design must be optimised to suit the characteristics of the individual odontocete sonar, a consideration of the wavelengths involved suggests that a common solution for the delphinid species, similar to the bottle-nosed dolphin, and for the smaller phocoenids seems to be practical. The acoustic characteristics required of a sonar reflector have been defined as follows:

(1) Echoes from the approaching odontocete’s sonar must be reflected directly back towards the animal, regardless of its approach direction in either azimuth or elevation.

(2) The device must be large enough (in acoustic terms) to intercept and return a specula echo with sufficient energy to become a more detectable target than that from the largest fish normally foraged for. The individual devices should be detectable at the maximum search range of the animal.
(3) The reflecting devices must not generate echoes which can be incorrectly classified as 'food-like' or the devices may function as attractors.
(4) The distribution of the devices across the face of the net must be perceived (at close range) as an impenetrable barrier.

These minimum parameters have been quantified, largely through detailed studies of wild bottle-nosed dolphin foraging behaviour, and several physically small prototype reflectors have been engineered which appear to meet these requirements. For a bottle-nosed dolphin foraging in relatively shallow water, a reflector with a Target Strength of approximately -34dB (ref a 2m radius sphere) appears to be optimal. To date, only the ellipsoid design has been tested with wild dolphins (Moray Firth Trials) but since the results of those tests have been consistently better than predicted, it was used in the Cornish gill-net evaluation.
Note: This ellipsoid reflector, a commercially available deep water fishing net float, meets most (but not all) of the desired acoustic parameters but the assessment of its handleability in a commercial fishing environment suggests that some shape and attachment improvements may be required.

RESULTS AND OBSERVATIONS The sonar images obtained, typified by figures 2 and 3, demonstrate that the difference in acoustic detectability between the modified and un-modified panels is very marked and that the reflector modification effectively infills the 18m deep 'gap' between the headline and leadline. The flat calm trial conditions were very favourable for this sonar study and in these conditions the side scan images reveal considerable detail. The method of attachment of the reflectors, although experimental, functioned well during shooting and recovery although a potential for snagging may exist. A braided tubing was chosen to support the reflectors since this does not twist under tension and was intended to smoothly guide the devices while shooting to reducing the likelihood of the reflectors catching into adjacent net layers. However, the wet braided tube trapped air bubbles which were slow to disperse and the consequent additional buoyancy hindered the net from quickly achieving its correct fishing geometry. The presence of trapped air in the braided tubes also appeared to temporarily enhance the acoustic Target Strength. The most significant handling problems occurred while transferring the wet net after recovery between the net storage 'pounds' preparatory to re-shooting the net. Some improvement in the attachment method will be necessary before this technique can be applied in a large scale commercial test but the mounting problem should be simplified with a minor design change incorporated in the device moulding.

SIDESCAN SONAR IMAGES Figure 1 illustrates the net configuration employed in the gill-net trial. The first pair of 55m long panels were modified with a grid of acoustic reflectors spaced apart 2m horizontally and 3m vertically. A 10m wide gap was deliberately inserted as a potential 'passing place' between these. The remaining pair of panels was also separated by a 10m gap and the two 120m sections butted together. The reflectors in braided tubes formed vertical 'strings' attached to both headline and leadline. The complete net assembly, with marker dahn buoys attached by short bridle ropes to each end, was shot in very calm conditions in 50m water depth where it drifted throughout the period of study. The sidescan sonar was deployed 50m behind the vessel and a series of runs made with the tow-fish deployed between 15 and 20m depth at different ranges and angles to the experimental net. The sonar images all clearly resolve the acoustically modified panels even though one of these panels remained incorrectly deployed (folded) for much of the study period. Figures 2 and 3 are typical sidescan sonar images and the annotations indicate a number of interesting features.

A) Headline This was the most detectable component in these very calm test conditions. Note that in a rougher sea state, wave troughs will form which will mask the headline and its echoes from a horizontal (dolphin) sonar operating near the surface.

B) Leadline When viewed at 30 m range, as in Figures 2 and 3, i.e. by a sonar towed parallel, this echo component is easily detected. However the leadline constitutes a long 'thin cylinder' target structure and this strong echo (produced by the ensonified length dimension) is very directional. At all other angles, the detectability of the leadline component falls rapidly as the reflections are then directed elsewhere!

C) Aeration Very fine bubbles, created by the vessel's propellor, are driven several metres deep producing an acoustically opaque cloud which persists for quite long periods. An identical effect spread throughour the water column occurs when high sea states start to entrain air at the breaking wabe crests. Such an acoustic 'fog' can be seen to severely impair the detection range of a small odontocete's sonar.

D) Reflector enhanced panels Note these panels generate very detectable echoes and in-fill the vertical plane of the net between headline and leadline.

E) Unmodified net segments appear completely transparent, even at short range, with no detectable echoes returning fron this 18m deep net curtain.

F) Gaps, 10m wide passing places - these net 'ends' were defined by 4mm polypropylene vertical cords.

It should also be noted that an approaching dolphin can only resolve small objects within a 10° wide 'spotlit' zone directly ahead of its path. During its approach it cannot acquire a comprehensive picture of the whole structure, as it provides these by sidescan images, each of which took several minutes to scan at this resolution. At any instant, the dolphin can only resolve targets that are contained in range by the time interval between its 'clicks' and in angle by the very narrow ensonified cone (beam) projected ahead. Only the highest frequency part of the dolphin's transmission spectrum (the very short wavelength signal components) are capable of resolving the acoustic dimensions of the larger supporting component parts of a fishing net and in most sea state conditions and from most approach directions even these may be missed.

CONCLUSIONS The trials in the Moray Firth in 1991 and 1992 have demonstrated that the passive acoustic merking technique has considerable potential to deter small echolocating odontocetes from passive gill-nets. The Cornish test on a commercial fishing boat demonstrated that when devices are attached to a fishing net they function to effectively in-fill the relatively transparent zone between headline and leadline. The mechanical method of attachment to the nets needs improvement and the more efficient reflector designs now need to incorporate a safe/simple method of fastening them directly to the net mesh. For evaluation at sea, especially in an off-shore fishery, an accurate underwater tracking technique is required (Morphett & Woodward, this vol.) in order to localise positions and plot the underwater tracks of approaching cetaceans relative to the fishing net. Behaviour changes induced by deterrent modifications need rapid evaluation (in relatively small scale comparative tests) if the current reliance on gross 'body count' by-catch statistics is to be avoided in the short term.

ACKNOWLEDGEMENTS The Support of the Seafish Industry Authority (Hull), The Master and crew of the MFV Britannia V (FH121), Leach and Turner (Truro), The DRA (Bincleaves), the European Commission - Eurogroup for Animal Welfare, and the Conservation Foundation are gratefully acknowledged.

REFERENCES

Au, W.W.L. 1980. Echolocation signals of the Atlantic bottlenose dolphin (*Tursiops truncatus*) in open waters. In *Animal Sonar Systems* (Eds. R. Busnel and J.F. Fish). Plenum Press, New York.

Goodson, A.D. 1992. Enhancing gill net acoustic detectability: Initial handling trials at sea. In *Initial trials to increase Acoustic Detectability if Drift Nets used in the Albacore Tuna Fishery.* (Ed. J. Swarbrick). (Report No. 408, Seafish Industry Authority, Hull.

Goodson, A.D., Mayo, R.H., Klinowska, M. and Bloom, P. 1992. Initial field trial of a passive acoustic device to reduce entanglement of dolphins in fishing gear. Int. Whal. Commn Doc. SC/44/21.

Klinowska, M., Goodson, A.D., Mayo, R.H., and Bloom, P. 1992. Progress in the development of efficient warning devices to prevent the entrapment of cetaceans (dolphins, porpoises and whales) in fishing nets. ICES Conference, Rostock, Germany. Doc. C.M. 1992/N:17-Ref. B.

Mayo, R.H. and Goodson, A.D. 1992. Interaction between wild dolphins and a moored barrier; initial results from the 1991 Moray Firth Trial. Pp. 184-189. In *European Research* on *Cetaceans* (Ed. P.G.H. Evans). Proc. 6th Ann. Conf. of ECS, Sam Remo, 20-22 Feb. 1992, European Cetacean Society, Cambridge. 254 pp.

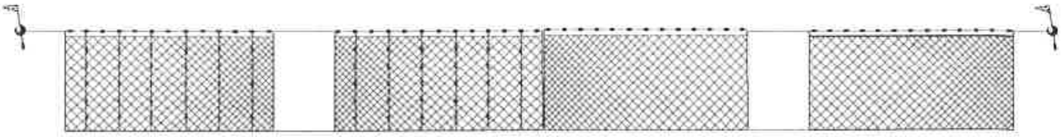

Figure 1 Configuration of experimental gill-net, total length = 240 m
4 off panels (each 55 m long by 18 m deep)
2 Modified panels with reflectors + 2 Unmodified + 2 gaps (10 m wide).

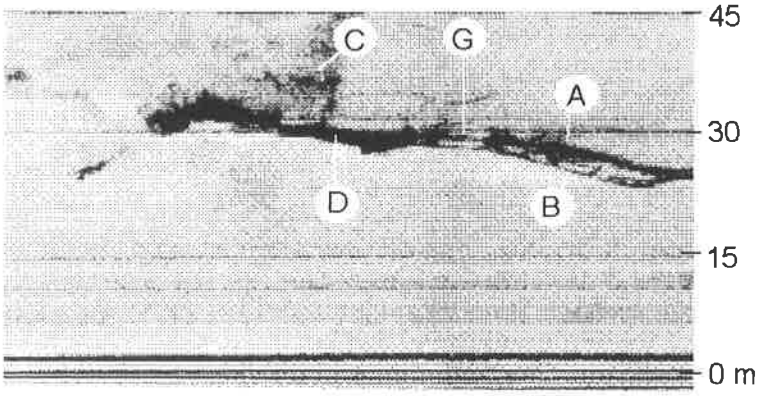

Figure 2 Sidescan image of gill-net - Acoustically Modified Mesh
A - Headline, B - Leadline, C - Aeration, D - Reflector modified panels,

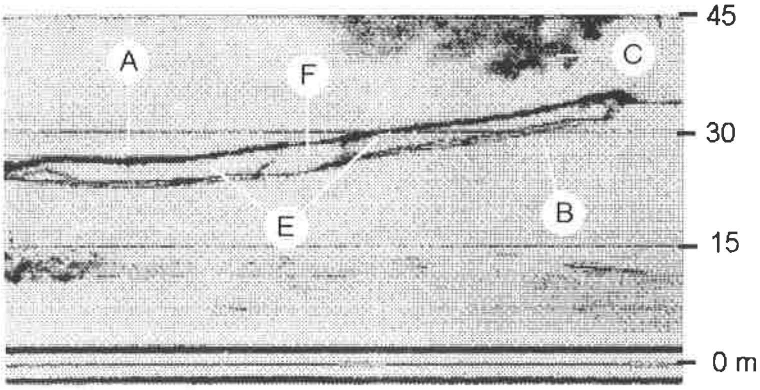

Figure 3 Sidescan image of gill-net - Un-modified Mesh.
E - Un-modified panels, F - Gaps.

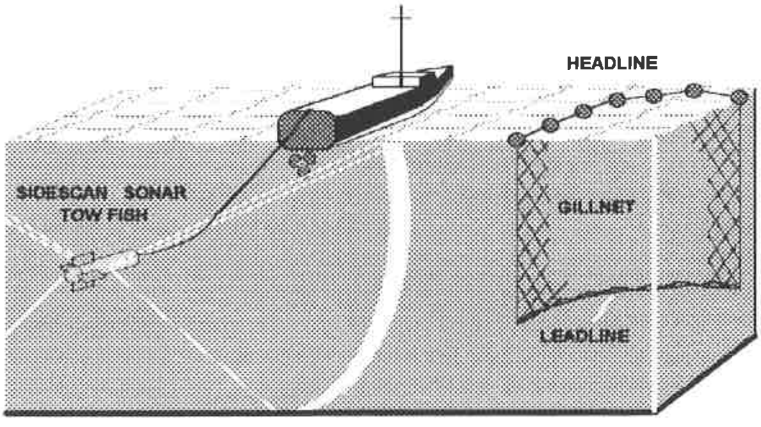

Figure 4 Sidescan sonar towfish deployment.

THE CHANGE OF ATTITUDES TOWARDS DOLPHINS FROM THE PAST TO TODAY

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This is not the result of a real scientific project. It is more a result of an intensive study of dolphins and human-dolphin interactions during a comprehensive film project in 1992.

In 1992, Greenpeace co-produced a seven part series about dolphins - their biology, variety, their beauty, and all sorts of human-dolphin interactions - positive as well as negative, friendly as well as harmfull, respectfull as well as disrespectful interactions. It was very interesting to see and to learn about the different attitudes of people towards these animals depending on their culture. We realised that there have been changes in attitudes from the past to today !

Over a period of six months, we filmed in twelve different countries in five continents, and we saw more than 2,000 dolphins of eighteen different species, thirteen species in the wild and twelve species in captivity. We also met a variety of people and cultures: indigenous people children, scientists, fishermen, conservationists, people with a very intense relationship with dolphins and people, who did not care about dolphins at all.

Dolphins played an important role in myths, sagas and songs all over the world for thousands of years. In ancient Greece, dolphins were seen as a symbol for the vitality of the oceans. Ancient Greeks worshipped them like gods. They often carried symbols with them as a talisman, like a coin with a dolphin on it or a small dolphin figure. In the temple of Kronos, which is more than 3,000 years old, you can see how much effort they put into showing the beauty of these animals.

The Roman writer Plinius wrote beautiful stories about the friendship between children and dolphins. In Northwest America, especially, the orca was an outstanding animal for the natives, a symbol of strength and power. Orcas were often used as the dominant figure in totem poles. In Australia the dolphin called Dingingaba is part of the dream world of the Aborigines. They play an important part in songs and traditional dances.

A form of co-operation between wild dolphins and fishermen has existed for generations in some parts of the world, for example Brazil and Mauritania (Northwest Africa). The dolphins drive fish towards the shore and straight into the fishermen's nets, and in casting their nets the fishermen drive some of the fish towards the dolphins. In this way, both have an easy catch.

Nowadays. dolphins are still seen as friends of humans in almost all cultures and parts of the world. Sometimes they are even seen as a sort of super-animal. People love them because of their beauty, intelligence, or complex social system, or because of their perfect adaptation to the marine environment and the grace of their movement in water; we humans still behave and move quite helplessly compared with the swimming style and grace of the dolphin's movement in water. The growth of the European Cetacean Society is as good an indicator as any that cetaceans are of special interest is to scientists as well.

People have also realised that also it is possible to make a lot of money from dolphins. Dolphins in dolphinaria or zoos are a big attraction. Also in the wild, in Monkey Mia (Southwest Australia) for example, dolphins are a major tourist attraction. Here, bottle-nosed dolphins are fed by rangers so these animals come very close to shore and people can even touch them. The Whale and dolphin-watching business is increasing almost everywhere in the world.

Swimming with dolphins in captivity and in the wild has also become a growing business. The good image of dolphins has also been used frequently by the advertising industry, even in Japan. But recent years have seen a lot of harmful, even destructive, attitudes towards dolphins. Unfortunately, dolphins are a very good example of our ambivalent attitude towards nature.

The United States has, on the one hand, such strong laws for the protection of marine mammals that private people are not even permitted to get closer than 100 metres to dolphins or large whales, but the United States tuna fleet is still allowed to kill 20,500 dolphins each year. It seems that the law here is not a Marine Mammal Protection Act but a "Tuna Industry Protection Act". Dolphins were used as pilots in the tuna purse seine fishery, especially in the Eastern Tropical Pacific, and millions of them have been killed during these operations in the last thirty years.

Fisheries are in general a huge and deadly problem to dolphins almost everywhere. The Baiji, (the Chinese river dolphin), is almost extinct, mainly because of fishing activities with set nets, rolling hook and dynamite fishery.

Illegal driftnet fishing kills thousands of cetaceans every year. Worst of all, in another fishery-related problem, people in various areas of the world are blaming marine mammals for the decrease in their catch. They kill dolphins and other marine mammals just because dolphins have the impudence to eat fish as well !

Pollution and habitat degradation often also reflect human ignorance towards other creatures and nature in general. People, or rather some people may be able to get accustomed to polluted water and shores; dolphins cannot.

The situation of belugas in the St. Lawrence is unfortunately a very good example of what pollution can do to dolphins. Because of their place in the food chain they accumulate in their bodies pollutants which are derived mainly from the aluminium, and pulp and paper industries. This causes many animals to be sterile, deformed and, even worse, for genetic material to be affected. Belugas which are still able to mate will pass this damage to the next generation.

But despite all the sad stories, it seems that there has been another change in attitude towards dolphins and nature in the last few years. Lots of individual people and organisations are working against this destructive attitude. They protest and fight against the disrespectful killing of dolphins and destructive and harmful fishing activities. These activities have resulted in the ban on high sea driftnets.

People are starting to question whether humans have the right to keep dolphins in captivity just for their own entertainment. Some dolphinaria have already closed down because of the lack of visitors, and release programs are even being discussed and started.

Many scientists have also changed their methods, and developed non-invasive techniques like photo-identification.

Although many populations of small cetaceans are endangered or under serious threat, this current development of a more respectful attitude is very encouraging, and gives hope of a good chance for the survival of these fantastic creatures.

EFFECTS OF WHALE-WATCHING VESSELS ON THE SURFACE AND UNDERWATER ACOUSTIC BEHAVIOUR OF SPERM WHALES OFF KAIKOURA, NEW ZEALAND

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Possible disturbance due to whale watching vessels was investigated by analysing both visually observed surface behaviour, and the patterns of vocalisations made by diving whales (which was taken as an index of the whale's underwater behaviour). Considerable variation in both undisturbed behaviour and reaction to vessels was found between individual whales. Some individuals which seemed most tolerant of vessels and were encountered along the continental shelf edge, received the most attention fron whale watching boats. However, even these tolerant whales showed some significant effects due to the presence of whale watching vessels; their blow rates were higher, surface times were shorter and there were changes in the nature of the first bout of clicking.

Although the effects observed do not appear to be substantial, it would be premature to conclude that they had little biological significance. There were also indications that the adoption of guidelines for whale watching operators had resulted in reduced levels of whale disturbance.

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AGE DETERMINATION OF NARWHALS (*Monodon monoceros* L.)

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INTRODUCTION Dentine of the embedded tooth and mandible layers have previously been described and found to provide a valid index of age for narwhals (*Monodon monoceros* L.) (Hay, 1980). However, the embedded tooth occludes due to closure of the root by enveloping cementum after the deposition of 10 to 20 dentinal growth layers, making the dentine little usable in older animals. Furthermore, the chance that a part of the root may remain in the skull when removing the tooth, and the problems of distinguishing between primary and secondary layers, constitute additional problems.

Up to 50 mandibular periosteal layers are deposited in male narwhals, which has a positive net accumulation of these layers throughout life, in spite of the resorption of several first-formed layers. Females, on the other hand, deposit a maximum of only 30 mandibular periosteal laters, suggesting that females approaching physical maturity have no additional accumulation of these layers.

Cementum is used as a reliable method for ageing in many other marine mammals. It has previously been stated that cementum surrounds the entire embedded tooth from root to tip except when the pulp cavity is open (Hay, 1980). In addition, it has been stated that this cementum is extremely thin and that the proximal cement at the root is contorted and marbled and does not present a layered appearance.

Narwhals have never been kept in captivity, so that calibration of observed layers to known ages has not been possible. It has previously been suggested that narwhals deposit 2-3 annual layers until sexual maturity, and thereafter only one annual layer (Hay, 1980).

MATERIALS AND METHODS The present study investigated the cementum of the tip of the embedded tooth in a small sample of 56 narwhals from Thule District, North West Greenland. The tooth tips were decalcified and longitudinally thin sectioned (14μ) and stained with a standardised toluidine blue, following Dietz *et al.* (1991). This procedure provided a readable display of translucent and opaque bands in the cementum deposition.

Narwhals and white whales *(Delphinapterus leucas)* are the only true members of the family *Monodontidae*. They live in the same areas and have a similar behaviour, appearance and size. A comparison of growth in these two species therefore seems reasonable. Data on length and number of growth layer groups (GLG's) from 65 male and 90 female narwhals from North-east Canada (Hay, 1980) and 130 male and 160 female white whales from West Greenland (Heide-Jørgensen & Teilman, 1993) were fitted to a Gompertz growth model; STD = STD ∞ exp(b-*exp(-kx)).

RESULTS Cementum, dentine and mandible were all correlated, but deposition of cementum and dentine tends to cease at about 20 layers. All indices also correlated with the length of the animal.

The precise same growth throughout life was observed if the number of layers deposited every year is the same for the two species (Fig. 1).

CONCLUSIONS The cementum on the tip of the embedded tooth of narwhals consists of easy readable layers. The easier access to the tip of the tooth, and the better readibility, makes the cementum more attractive for age determination than the dentine in narwhals. However further research is necessary to determine if the deposition of cemental layers stops at a certain age.

Growth comparison of narwhals and white whales shows a similar growth throughout life. Captive white whales have verified an annual increase of two GLG's (Goren *et al.*, 1993; Heide-Jørgensen *et al.*, 1993), so that it seems likely that narwhals also deposit two annual GLG's.

REFERENCES

Dietz, R., Heide-Jørgensen, M.-P., Härkönen, T., Teilmann, J. and Valentin, N. 1991. Age Determination of European Harbour Seal, *Phoca vitulina.* Sarsia, 76: 17-21.

Goren, A.D., Bridie, P.F., Spotte, S., Ray, G.C., Kaufman, H.W., Gwinnett, A.J., Sciubba, J.J. and Buck, J.D. 1987. Growth layer groups (GLG's) in the teeth of the adult belukha whale (*Delphinapterus leucas*) of known age: evidence for two annual layers. Marine Mammal Science, 3(1): 14-21.

Hay, K. 1980. Age determination of the Narwhal, *Monodon monoceros* L. Int. Whal. Commn, (Spec. Issue 3): 119-132.

Heide-Jørgensen, M.-P. and Teilmann, J. 1993. Growth, reproduction, age structure and habits of belugas *(Delphinapterus leucas)* in West Greenland waters. Bioscience (submitted).

Heide-Jørgensen, M.-P., Jensen, J., Larsen, A.H., Teilmann, J. and Neurohr, B. 1993. Age determination of white whales *(Delphinapterus leucas).* Bioscience (submitted).

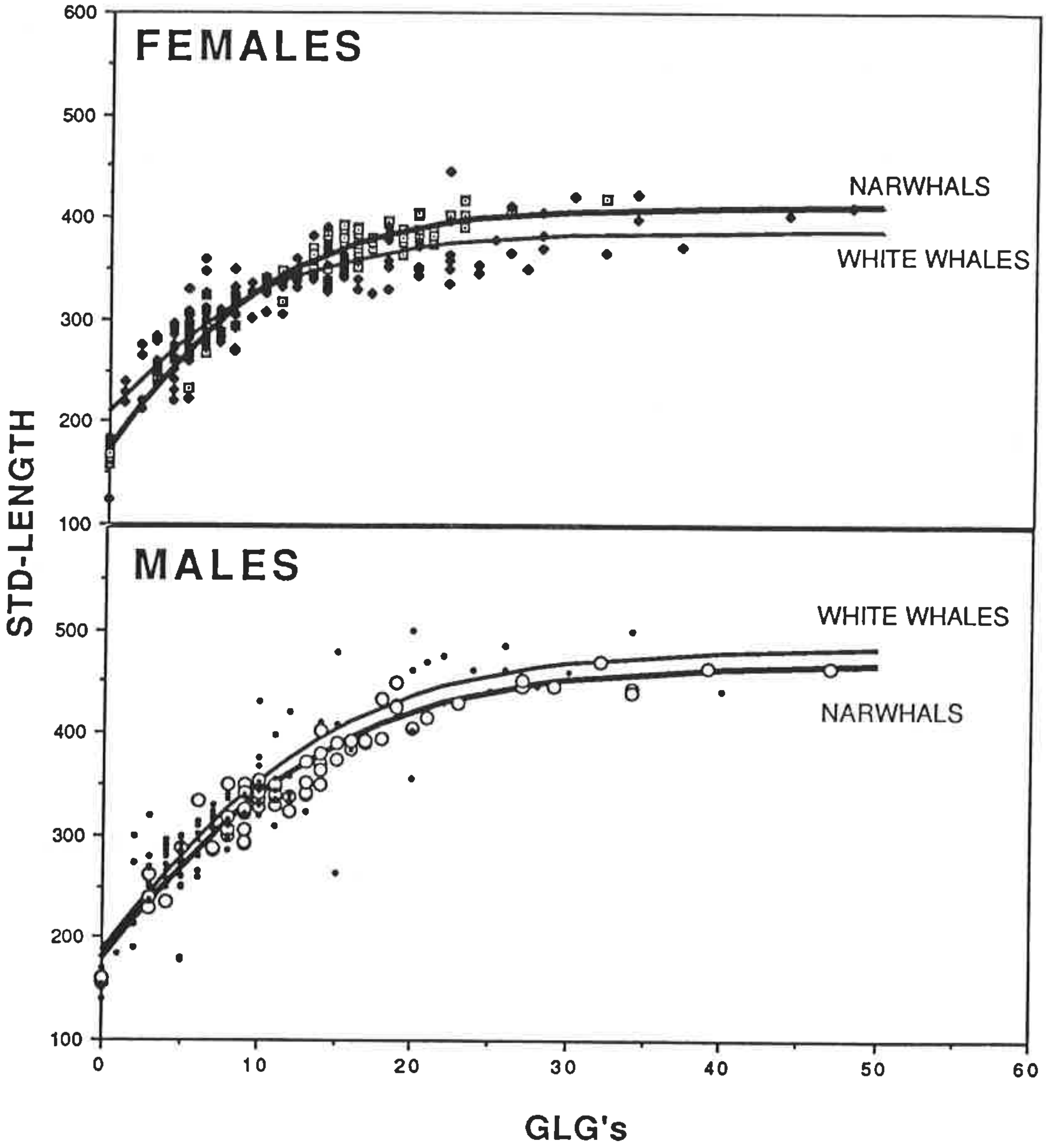

Fig. 1 Narwhal and White whale length frequencies in relation to GLG's

OBSERVATIONS ON THE ANATOMY OF THE INTESTINAL TRACT OF THE STRIPED DOLPHIN (*Stenella coeruleoalba*)

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This work describes for the first time the gross anatomy and histology of the intestinal tract of striped dolphin (*Stenella coeruleoalba*), obtained from an immature male discovered stranded on the Southwest coast of Ireland in mid-September, 1992.

The condition of the preserved intestinal tract was considored to be moderately good and the importance of the acquisition of freshly preserved material for such examinations is discussed. Gross histological anatomy are presented with some interesting findings, including the absence of several typically mammalian features. These and other characters are examined in an attempt to relate form and function. In addition, the results are assessed in terms of the biology of marine mammals as a whole, and in the light of increasing reports of striped dolphin strandings on the Irish coast, in terms of the biology of this species.

SKIN SENSIBILITY TO MECHANICAL VIBRATIONS (DEAF HUMAN SUBJECTS, DOLPHINS AND OTHER AQUATIC ANIMALS)

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A common image is that of a dolphin darting in the water sending out acoustic impulses to scan the environment in search of food and for navigation. But this mammal is also a body surrounded by an element which pulses with perturbances created by any movement in the water.

Most organisms that live in the aquatic environment have evolved extemely sensitive sensory systems to detect those perturbances, systems from which the acoustic apparatus of vertebrates, including man and dolphin, have evolved. The German psychologist and physiologist D. Kats pointed out the fact that the most primitive sense of animal organisms was that of *contact* ; feeling *mechanical vibrations* has represented a step further before the development of fine *auditory systems*. This is the process of vertebrate evolution towards perceiving distant mechanical stimuli, in the water first and secondly in air.

A finely adapted marine mammal like a dolphin is bound to have retained the basic neurological and psychological perceptive schemes together with the skin structure and innervation, of its class. It is therefore enlightening to study human sensibility to mechanical vibration especially in those deaf subjects that use the skin to feel what they cannot detect with their ears.

However, it is also necessary to search for any possible functional analogy with the structural and physiological adaptions of other aquatic animals, that is ichthyopsids (fishes) and amphibians.

The work being carried out is leading in those directions, and further correlates these studies with echolocation behaviour and lower frequency emissions by the dolphin. These have been discovered through parallel bio-acoustic research, recording the last stages of the search for a target, that is when the animal is bound to and touches the reflecting (resonant) object.

RESPIRATION PATTERNS OF FIN WHALES SUMMERING IN THE LIGURIAN SEA

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INTRODUCTION The Corsican-Ligurian-Provençal Basin, a part of the Mediterranean Sea framed between western Corsica , western Liguria and the French continental coast, was proposed for the creation of an international pelagic sanctuary for cetaceans (Notarbartolo di Sciara *et al.*, 1991).

In summer, large numbers of fin whales (*Balaenoptera physalus*), the most common mysticete in the Mediterranean, concentrate in this area. The level of boat traffic in the basin is high, and the instigation of conservation measures such as a sanctuary is likely to cause an increase in whale-watching activities in the Ligurian Sea. Therefore, it will be necessary to provide guidelines to avoid harassment of the animals. Since breathing may exert a greater influence on the behaviour of whales than of most terrestrial mammals (Würsig, 1984), the study of respiration rates (Stone *et al.*, 1992) could be a practical method to investigate potential disturbing effects caused by approaching boats.

The aim of this study was to collect baseline data to assess the feasibility of using fin whale respiration pattern variations to evaluate levels of disturbance in the Mediterranean Sea.

MATERIALS AND METHODS Research cruises were conducted aboard a 15m-long sailing vessel with auxiliary engine between 8 and 30 July 1992. Data were recorded for the longest possible time, until visual contact with the whale was lost.

Whales were followed at distances exceeding 100m in order to minimise affecting the animal's behaviour with the observers' presence; for the same reason, we waited for at least 15 minutes after the conclusion of other research activities (such as photo-identification, or the collection of biopsy samples) before monitoring the respiration of the animals. Minimum distance and time lag were chosen arbitrarily.

Respiration intervals were recorded to the nearest second using a digital clock. To avoid potential ambiguities due to contiguous surfacings of indistinguishable individuals, respiration times were recorded only from lone whales. Only complete dive-surfacing cycles were considered for the analysis.

A **dive** is defined as an interval between breaths lasting longer than 36 secs.; this cut-off time was determined by plotting the data on a log survivorship diagram (Fagen and Young, 1978).

A **surfacing sequence** is defined as the sum of intervals not exceeding 36 secs. between consecutive breaths.

A **cycle** was defined as one dive followed by a surfacing sequence.

In addition to length of dive and surfacing sequence, the following respiration parameters were also considered:

blow interval (the interval between successive blows during a surfacing);
- **number of blows per surfacing.**

The **blow rate** (number of breaths per hr) was calculated by dividing the number of blows of a dive-surfacing cycle by the duration of that cycle.

Respiration parameters were also related to different behavioural states. Arbitrary criteria for the discrimination of behaviour were swimming speed (travel = speed > 2 km per hr; rest = speed ≤ 2 km per hr), and duration of dive (long dive = dive > 6 min; short dive = dive ≤ 6 min). A combination of the above criteria resulted in the definition of four behavioural categories: short dive-travel (SDT), short dive-rest (SDR), long dive-travel (LDT), and long dive-rest (LDR).

RESULTS AND DISCUSSION 119 dive-surfacing cycles were timed from eight whales for a total of 13 hrs 15 min. of observation. Whales spent 29.25% of their time (Σ of surfacing sequences) at the surface. A summary of dive statistics is presented in Table 1. A significant difference in dive length was found between travel and rest; during short dives (unpaired t value 3.74; $p = 0.0003$); and during long dives (unpaired t value 2.54; $p = 0.0159$) (see Table 2).

Fin whales in the Ligurian Sea show a blow rate and a percentage of time spent at the surface considerably higher than comparable data given in the literature. As Hiby (1992) points out, surfacing rate estimates for fin whales are highly variable (between 30 and 72); also the amount of time spent at the surface varies between 13% and 25% (Stone, 1992).

It is unclear whether these discrepancies are caused by the different localities, by different behavioural states or, as reported by Hiby (1992), by the observer's effect. On the other hand, surfacing rates measured through land-based observations at great distance may be biased downwards as a result of the failure to observe some surfacings.

Future research should include the testing of different levels of "controlled disturbance" and examine possible relationships with the variability of respiration rates.

SUMMARY AND CONCLUSIONS Whale respiration patterns and frequencies vary in response to a number of external stimuli, including disturbance from approaching vessels. In order to assess the feasibility of using respiration pattern variations to evaluate levels of disturbance of fin whales by pleasure craft in the Mediterranean Sea, baseline data on the whales' respiration were collected in July 1992 in the Ligurian Sea. To minimise affecting the animals' behaviour with the observers' presence, whales were followed at distances exceeding 100 m; respiration times were recorded from lone whales only, to avoid potential ambiguities due to continuous surfacings of indistinguishable individuals. One-hundred and nineteen surfacing-dive cycles from eight whales were times, for a total of 13.26 hrs of observation time, allowing the calculation of the following respiration paraeters: blow rate expressed in time between successive blows ($n = 988$, mean = 48.34 sec., SE = 3.60), corresponding to the very high rate of 80.50 blows per hour; blow interval ($n = 869$, mean = 122.56 sec., SE = 7.89); and length of dive ($n = 119$, mean = 283.96 sec., SE = 19.11, mode = 128 sec.).

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REFERENCES

Fagen, R.M. and Young, D.Y. 1978. Temporal patterns of behaviour: durations, intervals, latencies and sequences. Pp. 79-114. In *Quantitative Ethology.* (Ed. F.W. Colgan). Wiley-Interscience, New York.

Hiby, L. 1992. Fin whale surfacing rate as a calibration factor for cue-counting abundance estimates. Rep. Int. Whal. Commn, 42: 707-709.

Notarbartolo di Sciara, G., Ausenda, F., Relini, G., Orsi Relini, L. 1991. Project Pelagos: proposal of a Biosphere Reserve in the Corsican-Ligurian-Provençal Basin. Pp. 21-23. In Proc.4th Intern. Colloq. on coastal and marine parks of the Mediterranean, Basia, 30 May - 1 June, 1991, Council of Europe.

Stone, G.S., Katona, S.K., Mainwaring, A., Allen, J.M. and Corbett, H.D. 1992. Respiration and surfacing rates of fin whales (*Balaenoptera physalus*) observed from a lighthouse tower. Rep. Int. Whal. Commn, 42: 739-745.

Würsig, B. Dorsey, E.M., Fraker, M.A., Payne, R.S., Richardson, W.J. and Wells, R.S. 1984. Behavior of bowhead whales, *Balaena mysticetus*, summering in the Beaufort Sea: surfacing, respiration, and dive characteristics.

Table 1 Summary of dive statistics

	mean	SE	n	mode
OVERALL BLOW INTERVAL (s)	48.34	3.60	988	15
LENGHT OF DIVE (s)	283.96	19.11	119	128
LENGHT OF SURFACING (s)	122.56	7.89	114	
BLOW INTERVAL (s)	16.08	0.17	869	15
NR OF BLOWS PER SURFACING	8.30	0.53	119	
BLOW RATE (h^{-1})	80.50	3.32	119	48.32

Table 2 Length of dive variation in different behavioural states (s)

	SHORT DIVE			LONG DIVE		
	mean	SE	n	mean	SE	n
TRAVEL	185.75	10.70	64	522.45	24.58	20
REST	105.70	17.20	20	622.67	31.65	15

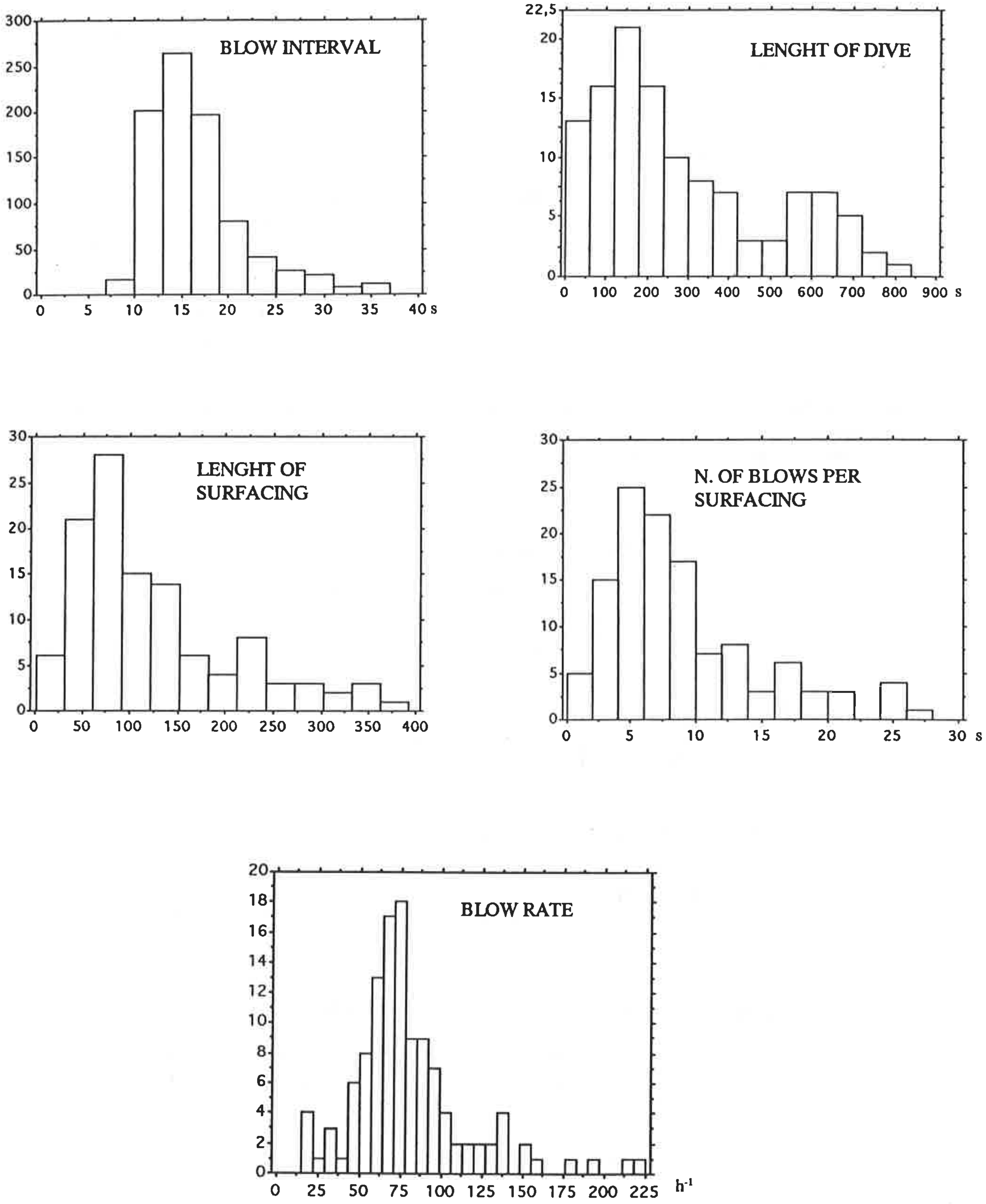

Fig. 1 Frequency distributions

RESPIRATORY PATTERN IN FREE-RANGING STRIPED DOLPHINS

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MATERIALS AND METHODS Six schools of striped dolphins (*Stenella coeruleoalba*) were sighted and approached in the Ligurian and Corsican Seas (42°50' - 43°43' N; 7°44' - 8°40' E) during a 12-day survey in July 1992, aboard a 51' motorised sloop. The animals were filmed with a video camera (Sony CCD-F355) at 50 frames s^{-1} while swimming near the boat. During all recordings, the camera height was about 3 m above the water surface. Accuracy of video speed was controlled by filming a stopwatch for several seconds. The boat velocity during the different sightings was assessed by time derivation of position data continuously obtained from a GPS system and it was considered representative of the average swimming velocity (U) of animals in that condition. This ranged between 2.3 and 3.7 m s^{-1} .

The time coded video recordings were subsequently analysed on a frame-by-frame basis with a temporal resolution of 0.02 s for the determination of the respiratory and locomotor timing. All values were expressed as mean ± standard deviation (SD). Statistical comparison between means was performed with a Student's t-test for unpaired data; the criterion for statistical significance was $p < 0.05$ throughout the study.

RESULTS AND DISCUSSION During this survey, 207 respiratory acts and the related surfacing were recorded in dolphins either swimming in undisturbed water away from the vessel or wave-riding the boat wake. In all the observed respiratory cycles the expiration started while the submerged animal was approaching the surface: it was apparent as a white cloud of bubbles radiating from the incompletely open blowhole and terminated with a spray of water coincident with the blowhole exposure to air. Inspiration was assumed to start after blowhole appearance and to last until the complete closure on entrance back into the water. The duration of locomotor behaviour enabling respiration was calculated from emergence of the nose to the re-entrance in the water of the most caudal part of the animal. Table 1 shows the average duration of locomotor and respiratory events.

Wave-riding and swimming behaviour Although wave-riding (wr) dolphins travelled at similar U compared with swimming (sw) animals (U_{wr}: 3.16 ± 0.32 m s^{-1}, n = 132; U_{sw}: 3.08 ± 0.44 m s^{-1}, n = 60, p = 0.14), their apnoea time (Ta) between consecutive breaths was significantly longer (Ta_{wr}: 17.54 ± 8.64 s, n = 55; Ta_{sw}: 11.66 ± 5.48 s, n = 47, p = 0.0001) and the respiratory rate (RR) was lower (RR_{wr}: 4.43 ± 2.52 min^{-1}, n = 55; RR_{sw}: 6.19 ± 2.70 min^{-1}, n = 47, p = 0.001), consistent with the energetic advantage inherent in wave-riding (Williams *et al.*, 1992) .

Surfacing pattern The duration of the surfacing (Ts) associated with respiration was linearly correlated with the average velocity as shown in figure 1, where the best-fitting line calculated with the least squares method is also shown. Two distinct locomotor patterns were observed during the surfacing manoeuvres: in surfacing defined as type A, the dolphin rolled at the surface, emerging with the rostrum first and re-entering the water with the *pedunculum caudalis* in a flexed posture as the last body portion. By contrast, in surfacing defined as type B, the animal re-entered the water with the extended tail and the fluke actually disappearing last. Type B surfacing, which occurred for a significantly longer time than type A (Ts_A: 0.736 ± 0.082 s, n = 116; Ts_B: 0.914 ± 0.078 s, n = 28, p = 0.0001), occurred also at a significantly higher velocity (U_A: 3.09 ± 0.35 m s^{-1}, n = 163; U_B: 3.41 ± 0.32 m s^{-1}, n = 28, p = 0.0001). Under these conditions, a significantly more elevated RR was also observed during type B surfacing (RR_A: 4.93 ± 2.52 min^{-1}, n = 86; RR_A: 6.90 ± 3.31 min^{-1}, n = 18, p = 0.0075). As can be seen in figure 2, the occurrence of type B surfacing increased progressively with velocity, thus suggesting that locomotor behaviour associated with respiration is controlled by a velocity-dependent mechanism. Moreover, inspiratory time (Ti) appeared to be significantly correlated with Ts, (see figure 3). On the other hand, no significant correlation was found between expiratory time (Te) and Ts. So it appears that the velocity-dependent pattern of locomotion does interfere with the control of respiration in such a way that at higher velocity (when metabolic requirements are greater), more time is devoted to inspiration, while expiration, occurring almost entirely during submersion, seems to be unaffected by this control. Such a trend contrasts with that observed in different terrestrial mammals (Ainsworth *et al.*, 1989; Lafortuna and Sabiene, 1991) and also in humans (Kay *et al.*, 1975) in whom, apart from the lack of apnoea between breaths, a reduction of Ti and an increase in tidal volume together with a rise in neural drive to the respiratory muscles, is observed as the metabolic requirement of exercise increases. Indeed, average Ti displayed by these dolphins is very short and, in consideration with the lung volumes expected in animals of this mass (about 100 kg), it may possibly imply constant activation of the respiratory muscle very close to the maximum. Furthermore, it is possible that dolphins breathe with very wide tidal volumes, as shown also by Olsen *et al.* (1969), who reported tidal swings encompassing almost 90% of lung air in the pilot whale. So the respiratory response to metabolic challenge may be modelled by a reduction in Ta during the dive, and by a slight increase in tidal volume achieved with an augmentation of Ti without significant increase in neural activation.

Emergence angle Assuming surfacing as a parabolic trajectory, the emergence angle (θ) was calculated from the swimming velocity (Us) and flight time (T). The tangent of θ, also expressed as senθ/cosθ, is given by the ratio between vertical (ULv) and horizontal velocity (ULh) during leap. Since ULh = Us cosθ and ULv = gT/2, it follows that senθ = gT/Us. The average Us and T measured during surfacing type A and B are presented in table 2, together with the calculated θ and ULh. It appears that θ adopted in type B surfacing entails an increase in T by over 12% with a sacrifice of only about 5% of ULv in respect of the values that would have been obtained if θ were not changed.

Leaping behaviour A third kind of locomotor activity, often referred to as leaping, consisting of a jump longer than one body length along a trajectory more than one body diameter above the water was often observed in sequences of 2-6 events when dolphins were swimming at an apparently relatively high velocity. Although leaping is considered as an energy saving method of locomotion for swimming above a critical velocity (Au and Weike, 1980; Alexander, 1989), respiratory activity was also evident in 23 out of 26 leaps, often despite the very short interval between the events. It is thus possible to argue that the respiratory activity may be reflexely linked to locomotor action. Although it is not known whether the central neural substrate or the afferent pathway triggers this reflex, this phenomenon recalls other aspects of co-ordination in mammals (Boudinette *et al.*, 1981) in terms of locomotor-respiratory coupling or respiratory activity anticipating locomotion, for which a possible role of hypothalamic networks co-ordinating locomotor and respiratory centres (Eldridge *et al.*, 1981) could be invoked.

CONCLUSIONS Striped dolphins cope with increased metabolic requirements by reducing the apnoea time between breaths and by increasing the duration of inspiratory time. The surfacing pattern associated with respiration is controlled by apparently velocity-dependent mechanisms. Moreover, it is postulated that surfacing and breathing are reflexely related, while respiratory timing may ultimately be actively controlled *via* those mechanisms which regulate locomotion at different swimming velocities by optimising flight times.

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REFERENCES

Ainsworth, D.M., Smith, C.A., Eicker, S.W., Henderson, K.S. and Dempsey, J.A. 1989. The effects of locomotion on respiratory muscle activity in awake dog. Respiration Physiology, 78: 145-162.

Alexander, R. McN. 1989. Optimization and gait in the locomotion of vertebrates. Physiol. Rev., 69: 1199-1227.

Au, D. and Weihs, D. 1980. At high speed dolphins save energy by leaping. Nature, Lond., 284: 548-550.

Baudinette, R.V. 1991. The energetics and cardiorespiratory correlates of mammalian terrestrial locomotion. J. exp. Biol., 160: 209-231.

Eldridge, F.L., Millhorn, D.E. and Waldrop, T.G. 1981. Exercise hyperpnea and locomotion: parallel activation from hypothalamus. Science, 211: 844-846.

Kay, J.D., Strange Petersen, E. and Vejby-Christensen, H. 1975. Mean and breath-by-breath pattern of breathing in man during steady-state exercise. J. Physiol. (Lond.), 251: 657-669.

Lafortuna, C.L. and Saibene, F. 1991. Mechanics of breathing in horses at rest and during exercise. J. exp. Biol. 155: 245-259.

Olsen, C.R., Elsner, R., Hale, F.C. and Kenney, D.W. 1969. "Blow" of the pilot whale. Science, 163: 953-955.

Williams, T.M., Friedl, W.A., Fong, M.L., Yamada, R.M., Sedivy, P. and Haun, J.E. 1992. Travel at low energetic cost by swimming and wave-riding bottlenose dolphin. Nature, Lond., 355: 821-823.

Table 1 Average timing of respiratory and locomotor events.

	mean (±SD)	**N**
velocity (m s^{-1})	3.14 (0.36)	207
Te (s)	0.318 (0.057)	151
Ti (s)	0.243 (0.056)	134
T apnoea (s)	14.83 (7.89)	102
RR (min^{-1})	5.24 (2.73)	102
Ts (s)	0.770 (0.107)	144

Notes: Te, Ti: expiratory and inspiratory duration; T apnoea, RR: duration of apnoea and respiratory rate calculated on subsequent respirations in series of 2 - 17 consecutive breaths; Ts: surfacing duration as defined in text; N = number of observations.

Table 2 Swimming parameters and calculated emergence angle for different kinds of surfacing.

	Us (m s-1)	**T (s)**	**θ (°)**	**ULh (m s-1)**	**TθA**	**ULhθA**
Type A	3.089	0.338	32.46	2.606		
Type B	3.412	0.419	37.04	2.723	0.373	2.879

Notes: US: swimming velocity; T: flight time; θ: calculated emergence angle; ULh: horizontal velocity during surfacing; TθA: flight time calculated with θ pertaining to type A surfacing; ULhθA: horizontal velocity calculated with θ pertaining to type A surfacing.

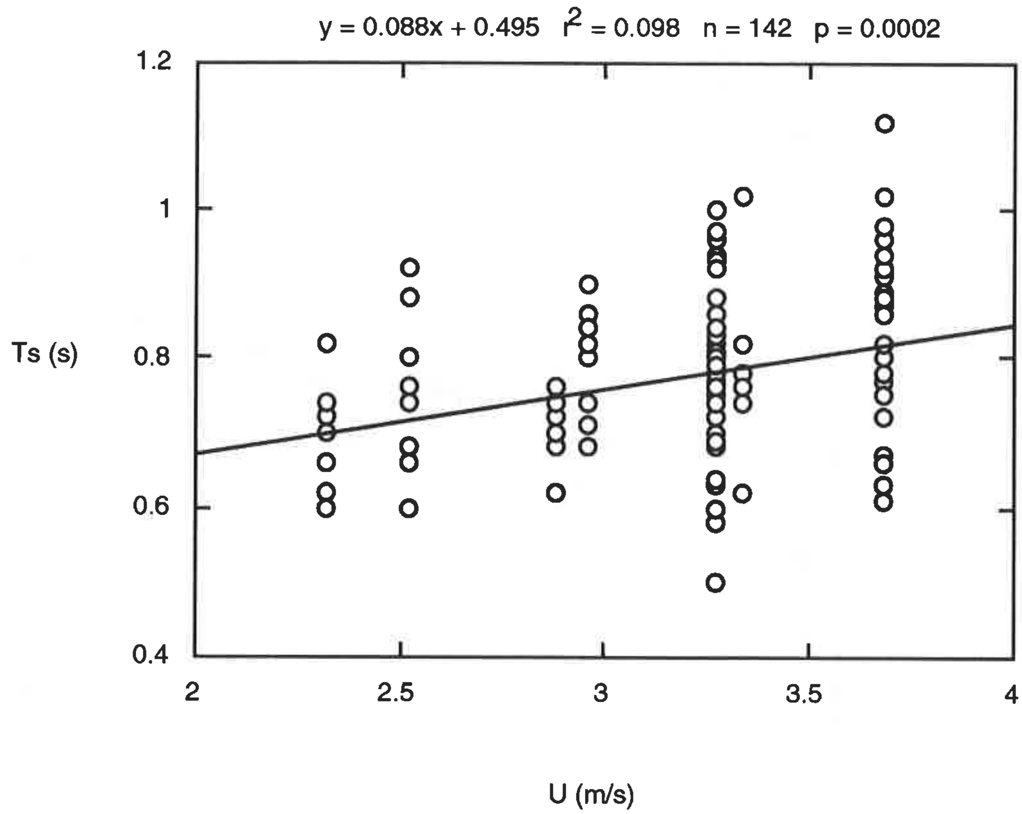

Figure 1 Relationship between swimming velocity (U) and surfacing duration (Ts).

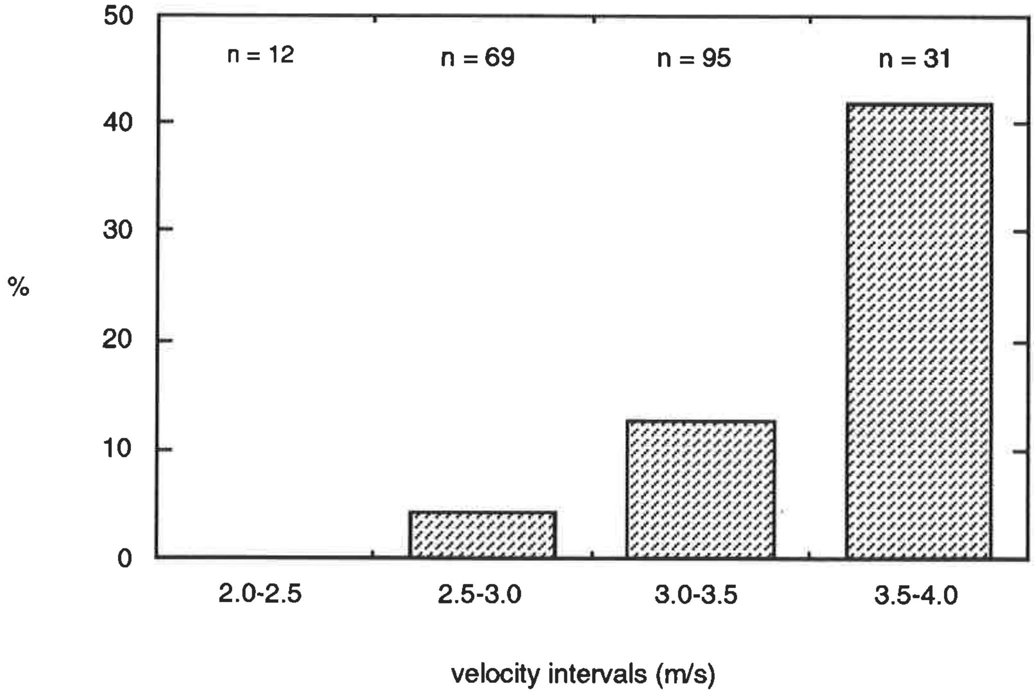

Figure 2 Surfacing type B (% of all surfacings) in the different velocity intervals. Figures at top indicate the total number of observations for each interval.

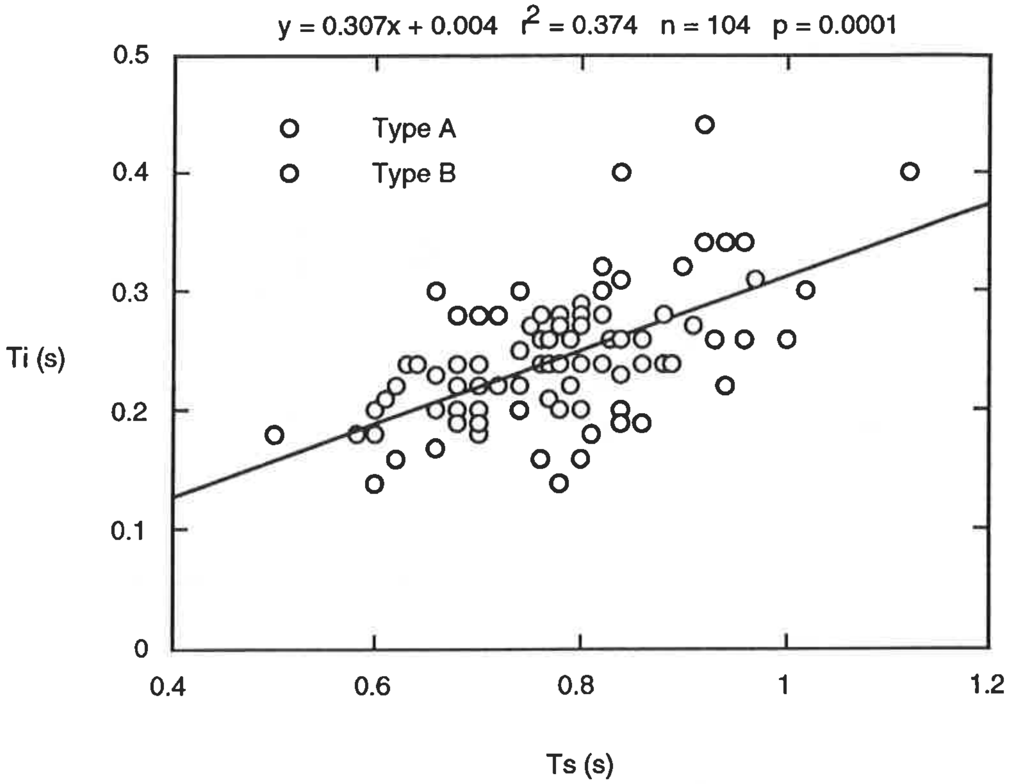

Figure 3 - Relationship between inspiratory time (Ti) and surfacing duration (Ts).

MEASUREMENT OF THE RESTING METABOLIC RATE OF THE ATLANTIC BOTTLENOSE DOLPHIN (*Tursiops truncatus*)

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INTRODUCTION Mammalian basal metabolic rates (BMR), defined as the metabolism of an adult which is post-absorptive, at rest and within its thermal neutral zone, can be predicted from the equation BMR = $3.28.M^{0.75}$ Watts, where M is the body mass in kg (Kleiber, 1975). Previous measures of metabolic rate in the Atlantic bottle-nosed dolphin actually reflect resting metabolism (RMR), defined as being at rest but not necessarily post-absorptive or thermo-neutral. The four published estimates of RMR suggest that these dolphins have RMRs 2-3 times higher than the BMR prediction. However, these measures were made on animals which may have been stressed by confinement and did not account for echolocation which in bats is known to be costly (Speakman *et al.*, 1989). We aimed to estimate the RMR of a captive dolphin, assumed to be unstressed, using a non-invasive technique and also accounting for the amount of echolocation to see if these factors might have produced artificially elevated estimates of RMR relative to the predicted BMR.

MATERIALS AND METHODS We measured the oxygen consumption, VO_2, of a single male three-year old dolphin, of estimated mass 100kg, using an open-flow respirometry apparatus. The dolphin was trained to exhale under a hood during two trained exercises: (1) stationed under the hood, exhaling immediately before going under the hood, then several times thereafter; (2) stationed under the hood, wearing eye-cups and echolocating, exhaling as above. Air was continuously drawn out of the hood and a subsample was pumped through an O_2 analyser. A hydrophone suspended from the hood monitored the presence or absence of echolocation pulses. These were recorded using a Racal tape recorder, as was a commentary of the animal's behaviour. The time between breaths, number of breaths, and percent time spent echolocating were later calculated.

RESULTS Total O_2 consumed (mls) was positively and linearly related to the number of breaths (Fig. 1) and the time over which breaths were taken (Fig. 2). The mean VO_2, for exercise (1) was 9.282 ± 0.681 mls. s^{-1} (equivalent to 186.4 ± 13.05 Watts assuming the respiratory quotient was 0.8). This was significantly higher than the Kleiber prediction (107 Watts) ($t = 3.35$, $p = 0.0058$) but only about half the value reported in previous studies. The relationship between VO_2 and percent total time spent echolocating (Fig. 3) marginally failed to reach significance ($F = 3.57$, $p = 0.088$). The RMR when the dolphin was wearing eye-cups, but not echolocating (zero intercept), was 5.54 ± 0.918 mls. s^{-1} (equivalent to 111.3 ±18.48 Watts). This was significantly different from that calculated for the exercise (1) ($t = 11.49$, $p > 0.001$) but was similar to the Kleiber prediction (107 Watts).

DISCUSSION Since the relationships between VO_2 and the number of breaths collected, or time between breaths, were linear, the dolphin exchanged an equal amount of O_2 per breath and the breaths were evenly spaced.

Figure 4 illustrates how previous measures compare with our results and with the Kleiber prediction. All previous measures involved prolonged contact with the apparatus and/or confinement which may have caused stress. It has been shown that handling of small animals can increase the metabolic rate by up to 65% (Hayes *et al.*, 1992). Also, Irving *et al.* (1941) used wild animals, one of which was injured. Our method was non-invasive, the only contact being with the eye-cups which the dolphin could easily remove itself. Also, the animal was bred in captivity and measurements were made in the pool in which the dolphin was normally kept.

From Figure 3, it was extrapolated that for a stationary dolphin echolocating constantly, the cost of echolocation was 1.83 x BMR. This appears, therefore, to be a costly system, the effects of which were not accounted for in previous studies and this may have contributed to the elevated RMR measurements.

CONCLUSIONS We suggest that previous studies may have over-estimated RMR in the bottle-nosed dolphin by not accounting for factors such as stress and echolocation.

ACKNOWLEDGEMENTS This work was carried out at Windsor Safari Park, Berkshire, UK We would like to thank Penny Gerstl and David Lindsay for training the animal and for all their help throughout the study.

REFERENCES

Hampton, I.F.G., Whittow, G.C., Szekerczes, J. and Rutherford, S. 1971. Heat transfer and body temperature in the Atlantic Bottlenose dolphin, *Tursiops truncatus*. J. Biometeor., 15(2-4): 247-253.

Hayes, J.P., Speakman, J.R. and Racey, P.A. 1992. Sampling bias in respirometry. Physiol Zool., 65(3): 604-619.

Irving, L., Scholander, P.F. and Grinnell, S.W. 1941. The respiration of the porpoise, *Tursiops truncatus*. J. Cellular and Comp. Physiol., 17: 145-168.

Kleiber, M. 1975. *The Fire of Life. An Introduction into Animal Energetics*. R.E. Kreiger Publishing Co., Huntington, New York. 454 pp.

Ridgway, S.H. and Patton, G.S. 1971. Dolphin thyroid: some anatomical and physiological findings. Z. Vergl. Physiologie. 71: 129-141.

Speakman, J.R., Anderson, M.R. and Racey, P.A. 1989. The energy cost of echolocation in pipistrelle bats (*Pipistrellus pipistrellus*). J. Comp. Physiol., 165: 679-685.

Williams, T.M., Friedl, W.A., Fong, M.L., Yamada, R.M. Sedivy, P. and Haun, J.E. 1992. Travel at low energetic cost by swimming and wave-riding bottlenose dolphins. Nature, Lond., 355: 821-823.

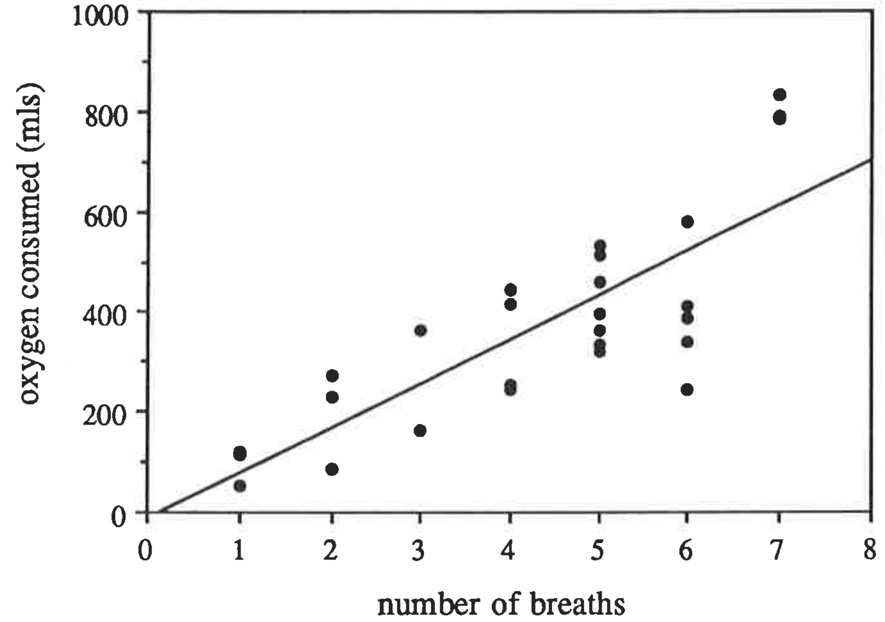

Fig. 1. The amount of O_2 consumed (mls) against the number of breaths made under the hood. The slope was significant, O_2 consumed = -13.7 + 89.0 number of breaths, $R^2 = 64.4\%$, p = 0.00.

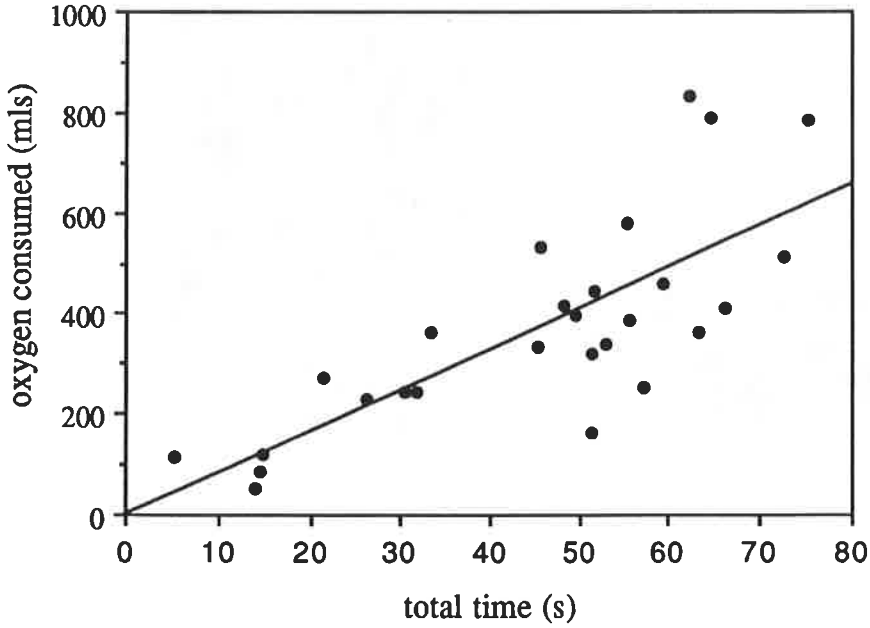

Fig. 2. Total O_2 consumed (mls) against total time (s), i.e. time between the pre-behaviour breath and the last breath made under the hood. The slope was significant (O_2 consumed = 1.72 + 8.2 mls.s^{-1}, $R^2 = 58.1\%$, p = 0.00).

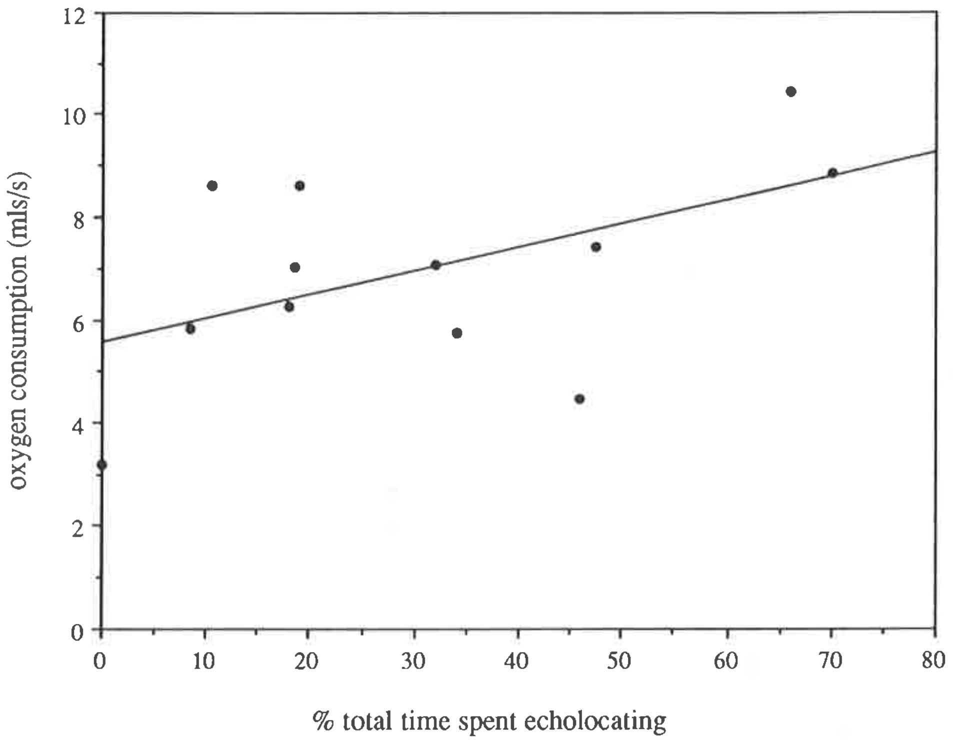

Fig. 3 O_2 consumption (mls.s^{-1}) against % total time spent echolocating for a stationary dolphin wearing eye cups. The relationship just failed to reach significance ($VO_2 = 5.54 + 0.0461\%$ echolocation, $R^2 = 26.3\%$, $p = 0.088$)

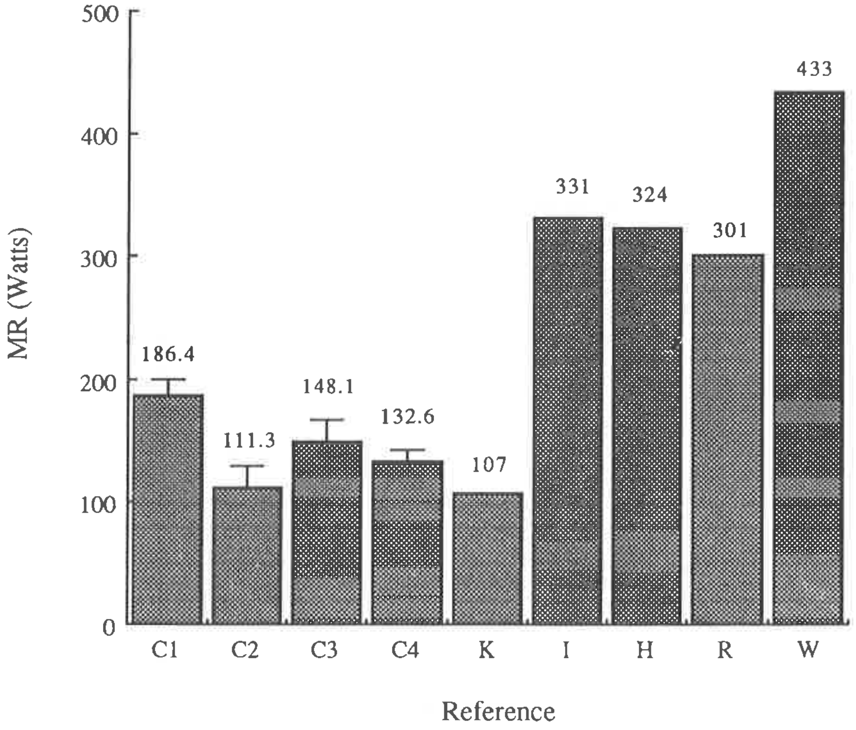

Fig. 4 Measures of RMR from the current invertigation plotted with previous measures and the Kleiber prediction for a 100kg animal. C1 and C2 = measurements from exercises (1) and (2) in this study, K = Kleiber, I = Irving *et al.*, 1941, H = Hampton *et al.*, 1971, R = Ridgway and Patton, 1971, and W = Williams *et al.*, 1992.

THE USE OF A COMPUTER-BASED EVENT RECORDER IN STUDIES OF THE SOCIAL BEHAVIOUR OF KILLER WHALES (*Orcinus orca*)

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INTRODUCTION The social behaviour of cetaceans is hard to study for obvious reasons, and killer whales are no exception. Since we are commonly restricted to observing the whales from the surface, it is important to be able to effectively extract information from their surface behaviour. By assigning social events, such as associations between individual whales, directly to their breathing pattern, one can test predictions drawn from hypotheses on social behaviour.

MATERIALS AND METHODS The studies were carried out in Tysfjord in northern Norway, in connection with the annual aggregation of killer whales in the period primo October to ultimo November. The whales aggregate to feed on the spring-spawning stock of Atlanto-Scandic herring (*Clupea harengus*), of which a major part winter in this small fjord system. The killer whales stay in the area until the end of January, but as the fjord is located well north of the Polar Circle, there is no light left by 1st December. It has been estimated that 4-600 whales may be present in the area during this period.

The data logger was constructed as a small hand-held panel, connected to an indoor portable computer (power-source: 220 V from a 12-220 V inverter supplied by the boat battery), and the panel was operated from the deck of a 31-ft, slow-going leisure-type boat.

Recordings were done continously, but different kinds of sampling methods were applied depending on type of study. When recording breathing pattern or looking for associations between specific individuals, focal sampling was applied, requiring the presence of individuals with pronounced markings, in order to enable recognition at a distance. When searching for a specific social event, such as the occurrence of male-calf pairs, scan sampling was applied. When recording group respiration pattern, behavioural sampling was applied.

RESULTS

Co-ordination of respiration Is the respiration sequence in a moving killer whale group random, or do the whales breathe in a co-ordinated, non-random manner, indicating social affinity between group members? A short breathing sequence of an average-sized killer whale group (10-12 individuals) moving in a chorus line, showed that the adult males initiated the breathing sequence of several individuals. This method of recording breathing sequence may also be of help when identifying the number of whales in a group of moderate size, and when searching for maternal subgroups that might be identified due to their respiratory integrity.

Co-ordination of foraging dive behaviour What role do different individuals have when foraging? Do adult males make dives of longer duration than subadult whales, which might be expected on the basis of their larger body mass? The dive patterns of NP-x and NP-3, shown in figure 1, were recorded over a two-hour period. These two whales did not associate closely, but moved around relatively independent of each other in a small area. Nevertheless, their dive profiles are similar, indicating co-ordinated foraging behaviour. The adult male, NP-3, does not exhibit dives of longer duration than the "non-male" NP-x.

Mother-calf association One focal whale, NA-2, thought to be the mother of the calf she associated with, was followed for nearly six hours. The dive pattern of NA-2 with and without her calf is shown in figure 2. During this period, she accompanied the calf (age 3 years or more) only 25% of the surface time (n=510). NA-2 exhibited longer dives when not accompanied by the calf. The amount of time that females spend with their calves is a function of both the age of the calf and her own previous experience as a mother. Due to the relatively small fraction of the time she associated with the calf one could expect her to be either an experienced mother or an alloparent.

Alloparenting behaviour When scanning for alloparental behaviour in an aggregation of whales, one needs to apply the strongest criteria to decide whether there is a "valid" association between two individuals, i.e. criteria for both the distance between the whales and the duration of an association. However, in the case of the two adult males KA-1 and KA-2 and their accompanying calf, strong criteria were not needed to determine the presence of alloparental behaviour since there were no other whales within visual range. Figure 3 shows the dive pattern of all three individuals and the calf's associate when breathing. All three whales showed respiratory synchrony and the calf had a clear preference to associate with one of the males, KA-1.

CONCLUSION Our experience is that the datalogger is simple both to construct and handle, and has the potential of being very useful in studies of killer whale social behaviour.

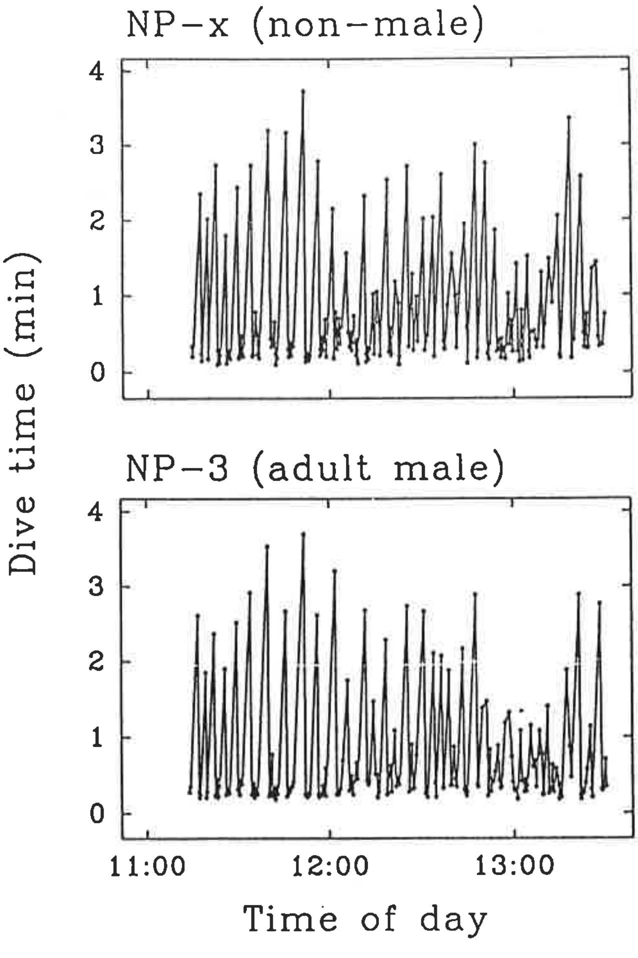

Fig. 1 Dive pattern of adult male NP-3 and "non-male" NP-x.

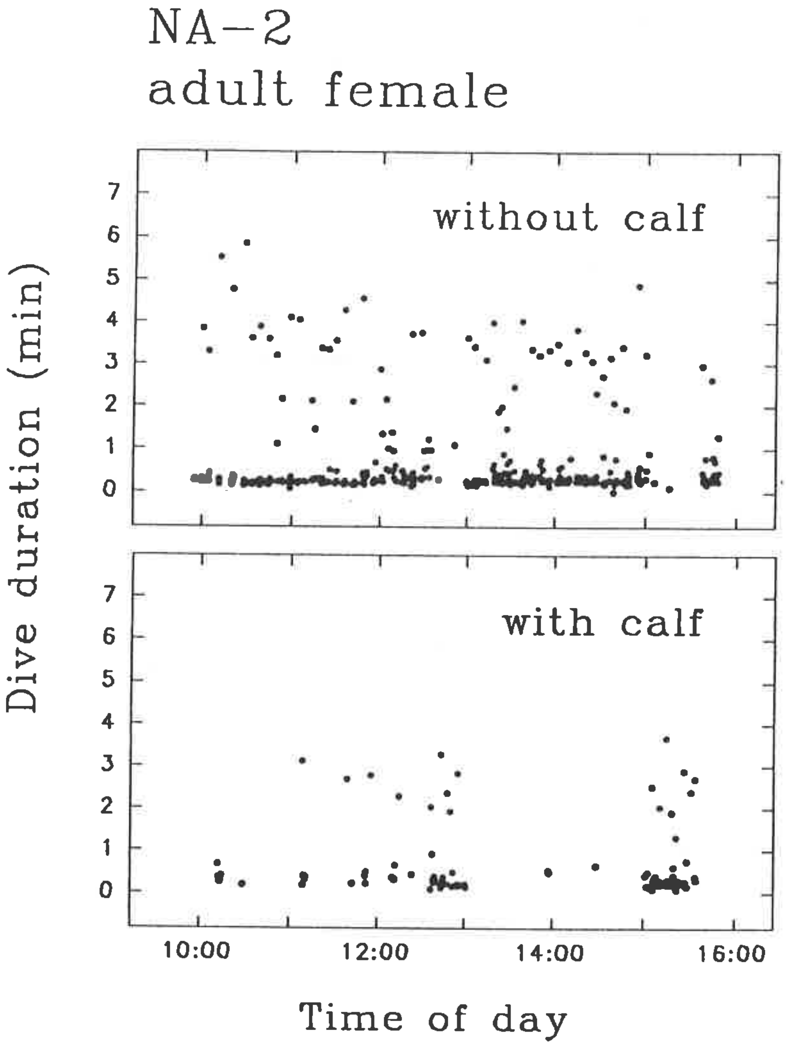

Fig. 2 Dive pattern of adult female NA-2 with and without calf.

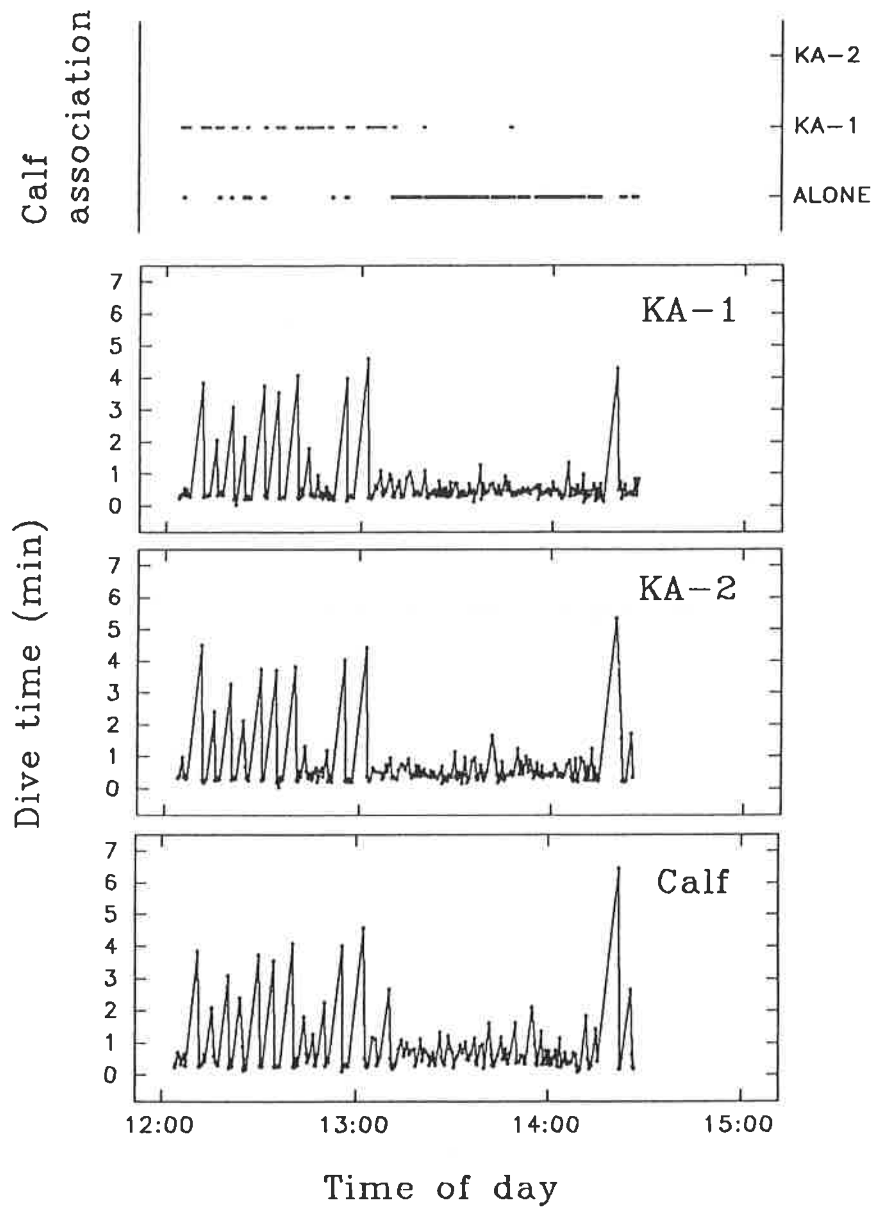

Fig. 3 Dive pattern of calf L-90 and associates; adult males KA-1 and KA-2.

USE OF A VIDEO SONAR AS A NEW TOOL TO STUDY MARINE MAMMALS

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The sonar SEABAT 6012 is delivering a real time video-like picture on a 90-degree field of view. This system was used for the first time at Sein Island (Western Brittany) to study the underwater activity of bottle-nosed dolphins (*Tursiops truncatus*) while fishing against the tidal current. With the sonar we were able to measure the total length of the dolphins as well as the speed of the dolphins while swimming underwater. Furthermore this system gave us information on the spatial distribution and movements of the dolphins while fishing against the tidal current. The 5 metres depth of the study area limited the range of the sonar to 50 metres, but a maximum range of 200 metres is allowed by this system if used in deeper waters. Future use of this new technology in marine mammal studies is also discussed.

INTEGRATING THEODOLITE AND VIDEO TRACKING DATA

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INTRODUCTION During 1991 and 1992, trials were carried out in the Moray Firth in which the reactions of wild dolphins to experimental passive acoustic reflectors configured to simulate a fishing net barrier, were examined (Mayo & Goodson 1992; Klinowska et al, 1992). These investigations set out to determine the dolphin's detection range and avoidance behaviour around obstructions to their normal swimming paths. The study method included:

(1) Clifftop observers logging event descriptions into a voice recorder.

(2) Underwater acoustic monitoring of the animal's acoustic emissions using sonobuoy telemetry recorded onto an instrumentation recorder, (the underwater sound being relayed to a loudspeaker near the observers);

(3) Theodolite tracking of the leading dolphin in each group traversing the test zone, plotting each surfacing position;

(4) A fixed video camera record of the central interaction zone, i.e. a barrier and approximately 100 metres of sea surface on each side (zoom angle and range dependent).

All of these data sources were logged with a common time code reference and, with the exception of the voice log, were recoverable to better than one second accuracy.

The theodolite image is necessarily highly magnified in order to achieve the high angular resolution of the instrument (a Sokkisha Set V). The instrument's telescope has a very narrow field of view which is approximately 13m wide at 500m range and angular measurements can be made to an accuracy of 20 secs. Figure 1 shows a view of one of the trial support vessels, taken through the theodolite telescope at approximately 600 metres range.

To achieve an unambiguous understanding of the observed behaviour, each of the different records needs to be examined in context. The underwater acoustic records of echolocation behaviour can reveal detail such as the initial detection range of the barrier, by measuring the inter-click period at the point where the onset of a 'locked' sonar transmission occurs. In some cases, the point of closest approach underwater can also be estimated from the inter-click period. Correlating such acoustic events to the theodolite surface track data rquires a very precise time frame and, since occasionally the theodolite may actually skip to track a different animal, the wide view provided by the video record may provide essential additional information.

The development of a synchronous display of the theodolite tracking data into the replayed video image is seen as a convenient way of integrating these data to a common frame of reference, and the automation of this process is the objective we set out to achieve. The processed video output (re-recordable) includes the underwater sound track, the television image of the interaction with an overlayed record of the theodolite pointing positions and a digital time display 'burned in'. Integrated data stored in this format provides a convenient summary of the events for study and for archiving.

METHOD The theodolite polar co-ordinate data is logged during a track as a sequence of three parameters: **Time** (Hours, Mins & Seconds); **Azimuth** the horizontal angle measured from magnetic North and; **Elevation** the vertical angle measured from the horizontal plane, (Mayo & Goodson, this vol.). These polar co-ordinates are normally processed into a Cartesian X-Y plane projection (Eastings & Northings) and plotted to give a dimensionally accurate plan view of events. For this new application, the unprocessed file of polar co-ordinates is transferred to an AT series computer and the data file read sequentially. The video tape, complete with a continuous EBU time code track, is played back and the time decoded and read by the computer. When the playback time matches that of the first data file record, the computer injects a cursor 'bright up' into the video image to highlight the position that the theodolite is pointing at. For the technique to work effectively, the video camera needs to remain locked to a fixed viewing position of the target zone, and the zoom angle needs to be constant. Once the cursor position has been manually registered wth the correct dolphin surface image, all the succeeding theodolite readings appear highlighted within the video image superimposed on the tracked animal's image. This composite image, together with a 'burned in' time reference, is re-recorded for later slow motion study. Should an incorrect surface position be selected at the first attempt, then succeeding surfacings will not register and the initial set-up operation will need to be repeated. However, in most cases the precision of the time coded information between the data sources (maintained to better than one second in practice, even with free running time references) is sufficiently accurate to ensure that the sighting is matched to the correct animal even when a large closely spaced group may otherwise be expected to cause confusion. At present, the computation of the displayed cursor position is based on prior knowledge of the camera's preset zoom angle, normally set to the maximum wide angle to encompass an adequate field of view. Should this not be the case, an additional calibration procedure is needed in which, having registered the first data point, the second data position is also manually overlayed onto the target. The 'on screen' cursor separation and the angular separation calculated from the theodolite data is then computed, and a corrected zoom angle scaling factor introduced for the subsequent points.

HARDWARE Although it is technically feasible to process the theodolite data and synchronise this with the video in 'real time', this was not judged to be a particularly useful facility as the operation of data capture can be frenetic. Restricting the technique to be an 'off line' analysis tool simplifies the task; the processing demands on the host computer cease to be critical and can be supported by almost any microcomputer. In the event, it was decided to build the hardware as a 'plug in' internal card, compatible with the standard IBM AT computer bus. In addition to this computer interface, an external time code reader is required which can translate the EBU linear timecode into a format that the microcomputer can read.

The replayed video signal is buffered on entering the computer card and the pulse timings are extracted from the composite video. A 'run-time' coding technique is employed to generate the cursor position by counting pixel positions along each TV line and switching the cursor image on or off at pre-computed positions. This method exploits an internal pixel clock synchronised by each TV line pulse to ensure that the inserted cursor image is stable. The TV line pulses are also counted (reset by the TV vertical pulse) to generate the cursor image in the vertical plane.

The shape of the cursor image is stored in memory as a 'look up table' of horizontal and vertical pixel addresses and these co-ordinate data are added to the required XY position on the screen. The XY position is computed from the theodolite co-ordinates and the cursor display enabled, when the associated time data matches the time read from the video recorder time code track.

The cursor image can be inserted into the analogue video data by simply switching the computed pixel positions to either black, white or grey, thus 'washing out' the data at this position on the screen. An alternative option uses the cursor pixels to generate a DC shift in the amplitude of the video image which simply brightens up the TV image at the cursor position without actually hiding any original image data. If the edges of the cursor outline reverse briefly from peak white to black level, this produces a high contrast display which enhances the visibility of the cursor regardless of the TV image intensity. Figure 3 illustrates the appearance of two alternative cursor displays overlayed on a calm sea target area.

CONCLUSIONS The system has yet to be used to analyse trials data collected, with the equipment set up for the technique. Fortunately, some of the 1991 & 1992 trials data were recorded with a suitable fixed camera position close to the theodolite and it has proved possible to insert the EBU time code data onto the sound track in order to generate 'real' data for testing. It is anticipated that integration of data in this way will significantly speed up the initial analysis and interpretation of tracking data. In particular, it ought to make the identification of parallel dolphin tracks much easier to isolate, i.e. where the theodolite observer has interpolated readings by sightings on other animals in a passing group. In the longer term, this may free the theodolite operator to employ 'snap-shot' sampling of multiple targets without any need to concentrate on a single lead individual. The technique has some limitation: it assumes that parallax effects are insignificant, i.e. the theodolite and camera need to be co-sited at a long range from the targets tracked. The low resolution TV image provided by standard VHS recording equipment is only acceptable in calm sea state conditions. Higher resolution formats, Hi-8 or S-VHS are more suitable and those cameras (Hi-8) which offer additional (digital and stereo FM) sound tracks can simultaneously record linear time code data, observer's commentary and the underwater sonobuoy telemetry sound. The timebase stability of the replayed video is important and replay systems which incorporate video timebase correction have a definite advantage. Gross timebase instabilities may upset the pixel clock oscillator resulting in distortion or slight movement of the overlayed cursor position.

The tool is still in an early stage of its development but a number of additional enhancements, such as the insertion of an overlay 'track line' on the TV image between the plotted points, together with 'id' tags or comments, seem feasible and may be implemented by simple software development. It is also hoped that it may prove practical to re-compute and display position data acquired from the new underwater tracking techniques (Morphett and Woodward, this vol.).

ACKNOWLEDGEMENTS The assistance of Mr. R. H. Mayo (Civil Engineering Department, Loughborough University) for the provision of theodolite calibration data and for the 1991 and 1992 Moray Firth track plots is gratefully acknowledged.

REFERENCES

Klinowska, M., Goodson, A.D., Mayo, R.H., and Bloom, P.R.S. 1992. Progress in the development of efficient warning devices to prevent the entrapment of cetaceans (dolphins, porpoises and whales) in fishing nets. ICES (Doc. ref. C.M. 1992/N:17-ref.B) at Rostock, Germany.

Mayo, R.H. and Goodson, A.D. 1992. Interaction between wild dolphins and a moored barrier; initial results from the 1991 Moray Firth Trial. Pp. 184-189. In *European Research on Cetaceans - 6* (Ed. P.G.H. Evans). Proc. 6th Ann. Conf. ECS, San Remo, 20-22 Feb. 1992. European Cetacean Society, Cambridge. 254pp.

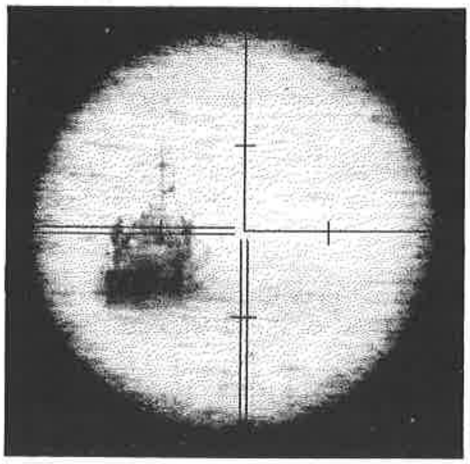

Figure 1 Theodolite image through telescope.

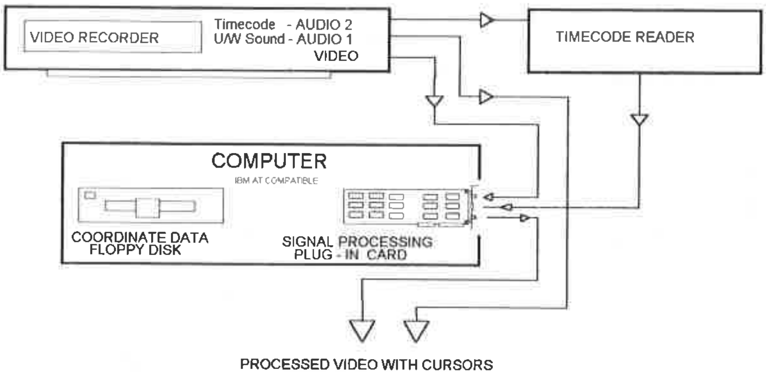

Figure 2 Block diagram of signal processing path

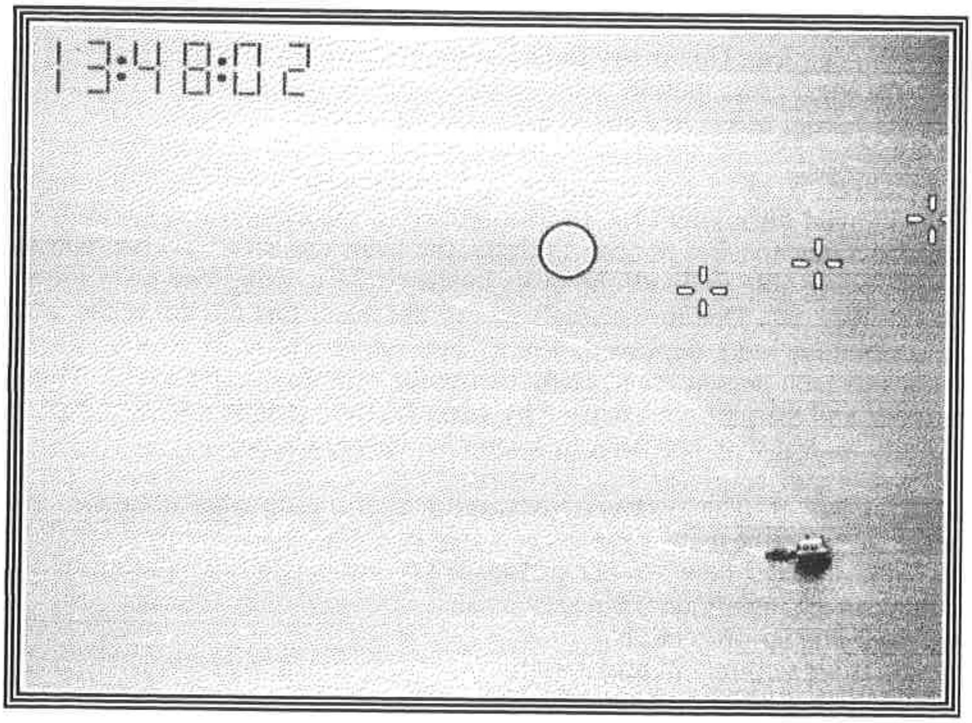

Figure 3 Cursor images overlayed on camera image of barrier zone.

CO-ORDINATING A DOLPHIN TRACKING FIELD TRIP

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THE MISSION UNDERTAKEN This contribution reviews the co-ordination of a mixed group of scientists, research engineers, dolphin trainers, students and other enthusiasts to undertake a fourteen-day field trial in the Moray Firth, Scotland. (Details of the trial involving the interaction of wild dolphins with a "barrier" deployed at sea, are presented in other papers at this conference).

The tasks to be accomplished were:
- Visually spotting the dolphins from a cliff top (daily betwen 0830 and 1900h)

The following then have to be simultaneously undertaken:
- Tracking the dolphins with an electronic theodolite
- Logging their positions on a data logger
- Videoing their movements and behaviour
- Voice logging their movements and behaviour
- Radio listening watch
- Recording them via radio telemetry from sonobuoy hydrophones

Further tasks had to be carried out, but not necessarily at the same time as the tracking procedures:

- Modifying the sonobuoys	(daily, usually at night)
- Deploying the sonobuoys/batteries	(daily, prior to observations)
- Data transfer	(after the day's observations)
- Transport of equipment between the trial base and the cliff top at 0815 and 1900h	
- Catering	(daily)
- Meetings with Aberdeen University field station, Dolphin Ecosse (the boat operators), the local press, public, schools etc.	
- Deploying the barrier at sea and retrieving it after the trial	

THE EXECUTION The team usually had about nine members (although the actual composition changed throughout the trial) to cover all the operations, some of which could only be done by a few specific people. Initially, the team was split into two alternating shifts with each team being able to do all the tasks independently, using one team for observations and one for catering, etc. Due to the small size of the team, this did not really work once the barrier and sonobuoys were deployed. The system which did work was to allocate specific tasks and times to each person the evening before the next day's operations. This covered all the regular work and the problems caused by weather, tide, fatigue and meetings. It also gave us the flexibility to deal with anything that came up during the day.

THE CONCLUSION The trial was successful, useful data were obtained, and the team worked well together. But there were aspects that could be modified by formalising the trial in four areas. The balance between the various areas will depend on constraints such as time, people, equipment and available finances.
- Planning, including co-ordination
- Training, including equipment preparation
- Operation, including areas of responsibility
- Review, initially for the team, later for publication

Although there is much that can be planned, there will always be unforeseen circumstances caused by weather, animals, etc. An enthusiastic team which is above all flexible and capable of adapting to any conditions is the most important factor in a successful trial.

Team formation The actual number of people in the team needs to be sufficient to cover all the tasks with a few extra to be available for problems or one-off major operations. For instance, deployment of the net cannot be guaranteed at a pre-determined time due to weather conditions, so making exact numbers and timing difficult to organise efficiently. However, adding only two people to the trial would considerably add to costs as more accommodation would have to be found.

Organising the team before the trial on a more formal basis would enable one to confirm the personnel actually available and allow for some training, especially of inexperienced field workers. One team member did not bring waterproofs to a cliff top in Scotland in September!

Any pre- or post-trial meetings, in order to plan and review preliminary data, will add to costs but will benefit the individuals and the team.

Technical operation and training All team members had their own special skills but varying abilities with the technical equipment, for example theodolite, video, data logger and recorders. As the trial progressed, most people learned to operate most of the equipment, although a few individuals could only operate a limited range of gear by the end of the trial. As a cliff top team had to be able to cover all the operations, while spotting dolphins, some form of pre-trial training would be beneficial. Written protocols or checklists would aid this training, as would more formal on-site training at the start of the trial. Checklists or colour-coding of items like battery connections would also help technical operations especially when fatigue becomes a factor.

Areas of responsibility and safety Often the team members will not be accustomed to working outside for long periods and so the effect of fatigue or illness will play a part in a 14-day trial. However, if people accept that it is a natural factor and not a weakness and speak out about this, it is easy to rotate the team to relieve any tiredness, particularly after a 24-hour watch or deploying sonobuoys at 0430 h due to the tide. It is a good idea to make one or two people responsible for looking for signs of strain, thus maintaining high standards.

Working on a cliff top, and with boats in the open sea, makes safety an important factor, and therefore experienced and practical people should preferably be responsible for the safety and efficiency of specific operations. A trained First-Aider and good emergency provisions are of course a necessity.

PERSONNEL ISSUES Operations such as modifying sonobuoys and data transfer could only be carried out by a few specific technical people. It was important to avoid over-tiredness as these jobs were usually done in the evening (even when they were not meant to be on the cliff, the team members often appeared there, especially David Goodson listening to his hydrophones!).

A relatively quick evening review and discussion of the day's work, attended by all the team, would be helpful to enable any comments to be made.

Initially, some team members were over-awed by all the "experts", but once it was explained everybody was important, this problem was overcome. The splitting of the team in the evenings either to work or to visit the local pub did not become a problem as everybody would help each other if required.

All the food preparation was done by team members as part of the rota and excellent meals were produced. Some people felt it almost became competitive and therefore affected the budget, but it gave everybody a change of pace from the observational work. One of the disadvantages of having a larger group would be the loss of everybody eating together in the evenings. The value of good meals cannot be over-emphasised as morale will quickly fall if people are not looked after well.

LOCAL COMMUNITY Due to adverse weather conditions, there was a delay in deploying the barrier. By taking the advice of Dolphin Ecosse (the boat operators), the operation was not rushed and when deployed, the net went in almost perfectly, without endangering people or boats. Help of this type from people with local knowledge made the trial the success it was.

Talks to school children and other interested groups were important for local relations and the future, even though people had to be allocated to do this, taking them from other duties.

Margaret Klinowska dealt with informing all the local organisations such as coastguards, landowners, RNLI, Aberdeen University Field Station, fishermen, etc. about the trial and the presence of a barrier in the water. In spite of all precautions, including extra marker buoys, one fishing boat did get very close. Even more markers might help with this problem and would also aid alignment of video and visual plotting.

It is a matter of flexibility, enthusiasm and common sense to rotate a team to fulfil all the roles, without leading to unsafe or inefficient working conditions.

LAND-BASED TRACKING OF CETACEANS - THE PRACTICAL USE OF SURVEYING INSTRUMENTS

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INTRODUCTION During September 1991 and September 1992, field trials were conducted in the Moray Firth, Scotland to investigate the reaction of a population of wild bottle-nosed dolphins (*Tursiops truncatus*) to a barrier of acoustic reflectors placed across the normal travel path. During these trials, and also during a 24-hour watch of a solitary bottle-nosed dolphin at Amble, Northumberland, England in January 1992, tracking techniques were developed employing electronic surveying instruments. These techniques are described in this paper, with the aim of assisting other observers in their use.

The basis of the method is to observe the points at which animals surface to breathe, and then to produce plans showing these points as a track. The instruments employed, electronic theodolites, are capable of measuring angles to high degrees of accuracy, typically 10 or 20 seconds of arc. If the height of the instrument above the sea level is known, simple trigonometrical equations enable plan co-ordinates - Eastings and Northings - to be calculated. The method is analogous to an observer standing and pointing to a point on the floor. An assistant makes a mark where the observer is pointing, and the finished track is the floor viewed from above.

THE INSTRUMENTS The measurement of angles is done using a standard surveyor's electronic theodolite, or a total station used as a theodolite. The instruments used during the Moray Firth trials were a Sokkisha (now Sokkia) SET 5 total station, with a Sokkisha DT4 theodolite as back-up. As described below, observations were made more comfortably using the SET 5, and this was used almost exclusively.

Surveying instruments are normally set up vertically above fixed points. For the Moray Firth trials, no fixed point existed on the cliff top, so one was created by driving a wooden peg into the ground and setting up over a nail in the top of the peg. This enabled observations on successive days to be made from the same point, and hence tracks produced to be superimposed on top of one another for comparison purposes. Indeed, the peg survived from 1991 to 1992, so that all tracks from the two trials are compatible. It is hoped that the peg will still be in place for future trials!

Having set up the instrument over the fixed point, the horizontal and vertical angles have to be zeroed. The vertical angle is usually zeroed from the horizontal plane through the instrument, and hence poses no problem. The horizontal angle, however, can be zeroed in one of two ways. One way is to pick a distant fixed point, sight on that, and zero the scale. Provided the two fixed points remain, this has the advantage that the sighting "North" does not vary, although it is not necessarily the "North" of conventional maps or plans of the area. The method used in the Moray Firth trials was to fix a compass to the instrument and zero to magnetic North. Of course, corrections for magnetic variation must be made if these are significant over the total timespan of the observations.

As described in the introduction, the basis for the method is similar to pointing to the floor. If, however, the observer's knees are bent, without moving the arm, the marked point moves. Obviously, the height of the survey instrument above the sea surface must be known to sufficient accuracy for adequate tracks to be produced. A complication, of course, is that due to tidal action this height varies during any period of observations.

One advantage of using a total station is that it can be used as an EDM (electronic distance measuring device) whereby, by placing a reflecting prism, on a pole, at the water's edge, the vertical height can be read directly from the instrument. If an EDM is not available, other methods, such as levelling from known bench marks, have to be employed, a process that may be very inconvenient. A technique, developed at the Moray Firth in 1992, simplifies the problem, however.

If a vertical surface wetted by the tide is visible from the observation point, marks can be made on this surface and levelled in at the beginning of observations. In our case, the vertical surface was provided by a series of rocks, into which masonry nails were driven. Each nail had a different coloured ribbon tied to it, which survived being exposed and submerged twice a day for a fortnight remarkably well. The EDM was used to measure the vertical height from the nails to the top of the peg over which the survey instrument was set up. On subsequent days it was then a simple matter of measuring the height of the instrument above the peg top in order to find instrument to nail heights.

The nails were observed, and the time at which each was at the sea surface level was recorded. A height versus time curve could then be drawn on site for each day of observations, as shown in Figure 1. As discussed below, if the time of each siting is taken, reference to the relevant curve will enable the instantaneous height to be read and used in subsequent calculations. A routine must be set up, however, to ensure that nail submergence or exposure times are read even when animals are being tracked; the reserve theodolite, if one is available, is useful for this purpose with the cross hairs of the instrument pre-sighted on the nail in question. If a second theodolite is not available, a pair of binoculars may be used, but reading may be more difficult.

An alternative height measuring technique was employed at Amble. Here sighting distances were relatively short (approximately 50 to 100 metres) and the instrument was set up on a pier wall. A weighted string was marked at 2-metre intervals and lowered until the weight was judged to be at average sea level. Counting the marks, and measuring the top interval, enabled construction of the height/time curves. The method was simple but effective.

Surveying instruments are normally used to sight static targets, visible for as long as is necessary. Surfacing dolphins (and porpoises) do not co-operate in this way, typical sightings lasting for about one second in a possibly unexpected position. The data logging program required to deal with this is discussed in the next section, but modifications in the use of the survey instrument may also be necessary.

The normal way of sighting is to align the target with the cross hairs in the instrument's telescope, using adjusting screws. This is satisfactory for animals observed at considerable distance (typically one kilometre) but for closer distances the field of view through the telescope may not be large enough to observe the surfacing, due to the unpredictable nature of the track. If observation is first made looking over the top of the instrument, only in exceptional circumstances will the surfacing point be visible as a "puddle" long enough for subsequent sighting with the cross hairs.

The survey instruments employed in our trials are fitted with external "sights" and, for observations of about 500 metres, these were used for actual sightings.

A preliminary assessment of the accuracy of this method has since been made on land, and further work is in progress. Due to the shallow vertical angle (approximately 5^o) any error in measurement of this angle produces a large error in range. A similar error in measuring the horizontal angle produces a much smaller error in transverse position. This should be borne in mind when choosing a position for the theodolite.

The shape of the instrument body may also influence its choice. The Sokkisha DT4 is a cylindrical telescope mounted between vertical supports, while the SET 5 is a rectangular prism 125mm x 150mm x 55mm, also mounted between vertical supports. Observers found it easier to hold the body of the SET 5 when making rapid readings using the external sights, and this feature may be worthy of consideration by others.

THE DATA LOGGER As mentioned above, dolphins and porpoises surface for a very short time, and data logging must therefore be simple and rapid. This section contains information on the current state of our art, though further improvements are doubtless possible.

We feel it is essential to have a two-man team making observations, one sighting using the EDM/theodolite and one using the data logger. The data logger operator must be able to work "head-up", looking out for surfacings. The data-logger used in 1991 was loaned by Sokkisha and set to a cycle time for repeat observations of about 10 seconds. Under some circumstances this was too long and the in-built clock (see below) only read to the nearest minute. In 1992, the data logger employed was a Husky Hunter, programmed for very simple data entry, recycling in about two seconds and with a clock reading to the nearest second.

In all our field trials, simultaneous observations were made using the survey instrument, two or more video cameras, one or more hydrophones for underwater acoustics, and separate voice log. Synchronising all these together afterwards would have been impossible without a standard time code accurate to at least one second. For most of the recording devices (the video recorders and instrumentation recorders), this is fed from an external EBU time code working to $\frac{1}{25}$ second. It is of course vital that times are regularly synchronised to avoid relative drift between this equipment and that running asynchronously.

The Husky Hunter has its own built-in clock, which can easily be set at the start of a day's observations; over a 24 - hour period the drift was found to be less than $\frac{1}{2}$ second. When the data logger operator sees a dolphin surface, he can press the T key to log the time at that instant, enabling subsequent reading of instrument/water level height from the curve currently being produced. If there is more than one animal travelling in a group, and the survey instrument operator is trying to stay with only one, the data logger operator must wait until commanded to take the time.

Once the surfacing has been observed, it is usually possible to move the EDM/theodolite to the correct position, and press another key (the P) to "grab" the required angles.

It is convenient at this stage to have the option of adding an alphanumeric comment to the reading, in our case initiated by pressing the Q key. The only trouble with this is that another surfacing may take place while the comment is being entered, preventing an accurate time being recorded.

Under some circumstances, a time may be recorded but the position lost by the theodolite operator. It simplifies things if a single key stoke can record an "abort" message and cycle back for the next time reading.

At the start of any logging session, it is usual to record the details of the observation point. However, these usually do not change during the day, and so need not be recorded each time a series of surfacings is recorded. Since field operations only have a limited battery life, it is considered useful to be able to leave the theodolite and data logger switched off, but to be able to get them to the recording part of the program very quickly once animals are sighted, even though this will generate an incomplete file heading.

RESULTS For the Moray Firth trials, files from the Husky Hunter were down-loaded every evening onto hard copy and floppy disc via a lap-top computer. A program was then run to interrogate the data files, and to produce Eastings and Northings as shown in Table 1. It can be seen that the time between successive observations is also calculated, as is the distance between surfacings. It is a simple extension of the program to then calculate the speed between the two points, although this is of course the land speed. A correction for tide flow must be made to arrive at swimming speeds.

At present, the Eastings and Northings are entered manually into the AutoCAD drawing package to produce tracks such as that shown in Figure 2. It is hoped to transfer this data automatically for future trials, and to produce plots on site.

REFERENCES

Mayo, R.H. & Goodson, A.D. 1992. Interaction between wild dolphins and a moored barrier; Initial results from the 1991 Moray Firth trial. Pp. 184-189. In *European Research on Cetaceans - 6* . (Ed. P.G.H. Evans), Proc. 6th Ann. Conf. ECS, San Remo, 20-22 Feb 1992. European Cetacean Society, Cambridge. 254 pp.

Goodson, A.D., Mayo, R.H., Klinowska, M. & Bloom, P.R.S. 1992. Initial field tests of a passive acoustic device to reduce the entanglement of dolphins in fishing gear. Int. Whal. Commn Doc. SC/44/SM21).

Klinowska, M., Goodson, A.D., Mayo, R.H. & Bloom, P.R.S. 1992. Progress in the development of efficient warning devices to prevent the entrapment of cetaceans (dolphins, porpoises and whales) in fishing nets. (Document ref. CM 1992/N:17 - Ref. B) International Council for the Exploration of the Sea. Rostock-Warnemunde.

Mayo, R.H., Goodson, A.D., Sturtivant, C. & Hayers, R.J. 1992. Non-intrusive tracking of *Tursiops truncatus* - breathing rates and swim speeds. EAAM Conference, Bruges.

Bloom , P.R.S. 1992. The diary of a wild, solitary, bottlenose dolphin (*Tursiops truncatus*), resident of Amble on the north Northumberland coast of England from April 1987 to January 1991. Aquatic Mammals.

Table 1 Numeric results - eastings and northings

```
            Tracking Reference No :      DOLPHIN TRACK 2 ON 14 SEPT 1992.
            Theodolite Height     :        53.89m.
            Number of Readings    :              9.

    Summary of Data Entered.
    ------------------------
------------------------------------------------------------------------------
| Reading |    Elevation Angle       |       Bearing Angle       |         Time          |
|   No    |         <degs>           |          <degs>           | <hrs>:<mins>:<secs>   |
------------------------------------------------------------------------------
|      1  |         96.9722          |         165.0360          |        13:55:35       |
|      2  |         96.8694          |         165.0610          |        13:55:42       |
|      3  |         96.8500          |         162.1330          |        13:55:49       |
|      4  |         96.9027          |         160.1830          |        13:56: 7       |
|      5  |         94.9166          |         154.2770          |        13:58:32       |
|      6  |         94.8222          |         152.2190          |        13:58:50       |
|      7  |         94.6083          |         150.7720          |        13:59: 3       |
|      8  |         94.4555          |         149.0080          |        13:59:22       |
|      9  |         94.6527          |         148.1440          |        13:59:28       |
------------------------------------------------------------------------------

|-------|-------|---------|---------|---------|----------|-----------|---------|
|READING|   XY  |NORTHING | EASTING |  TIME   | DISTANCE | DIFF TIME | L SPEED |
|       |  (M)  |   (M)   |    (M)  |(H:M:S)  |   (M)    |  (SECS)   |  (M/S)  |
|-------|-------|---------|---------|---------|----------|-----------|---------|
|   1   | 440.7 | -425.7  |  113.8  |13:55:35 |          |           |         |
|       |       |         |         |         |    6.66  |        7  |   0.95  |
|   2   | 447.3 | -432.2  |  115.3  |13:55:42 |          |           |         |
|       |       |         |         |         |   22.93  |        7  |   3.28  |
|   3   | 448.6 | -427.0  |  137.6  |13:55:49 |          |           |         |
|       |       |         |         |         |   15.60  |       18  |   0.87  |
|   4   | 445.1 | -418.8  |  150.9  |13:56: 7 |          |           |         |
|       |       |         |         |         |  189.31  |      145  |   1.31  |
|   5   | 626.5 | -564.4  |  271.9  |13:58:32 |          |           |         |
|       |       |         |         |         |   25.85  |       18  |   1.44  |
|   6   | 638.8 | -565.2  |  297.7  |13:58:50 |          |           |         |
|       |       |         |         |         |   34.05  |       13  |   2.62  |
|   7   | 668.6 | -583.5  |  326.5  |13:59: 3 |          |           |         |
|       |       |         |         |         |   31.12  |       19  |   1.64  |
|   8   | 691.6 | -592.9  |  356.1  |13:59:22 |          |           |         |
|       |       |         |         |         |   31.15  |        6  |   5.19  |
|   9   | 662.2 | -562.4  |  349.5  |13:59:28 |          |           |         |
|       |       |         |         |         |    0.00  |        0  |   0.00  |
--------------------------------------------------------------------------------
```

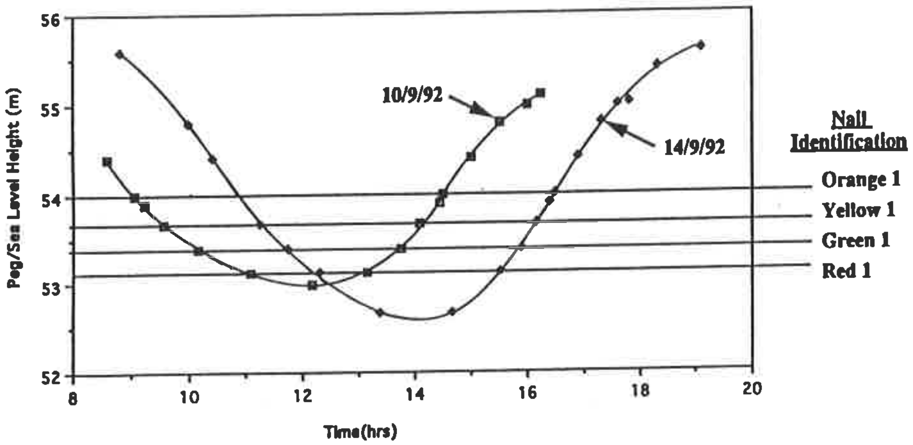

Figure 1
Peg/Sea Level Height vs. Time Curve

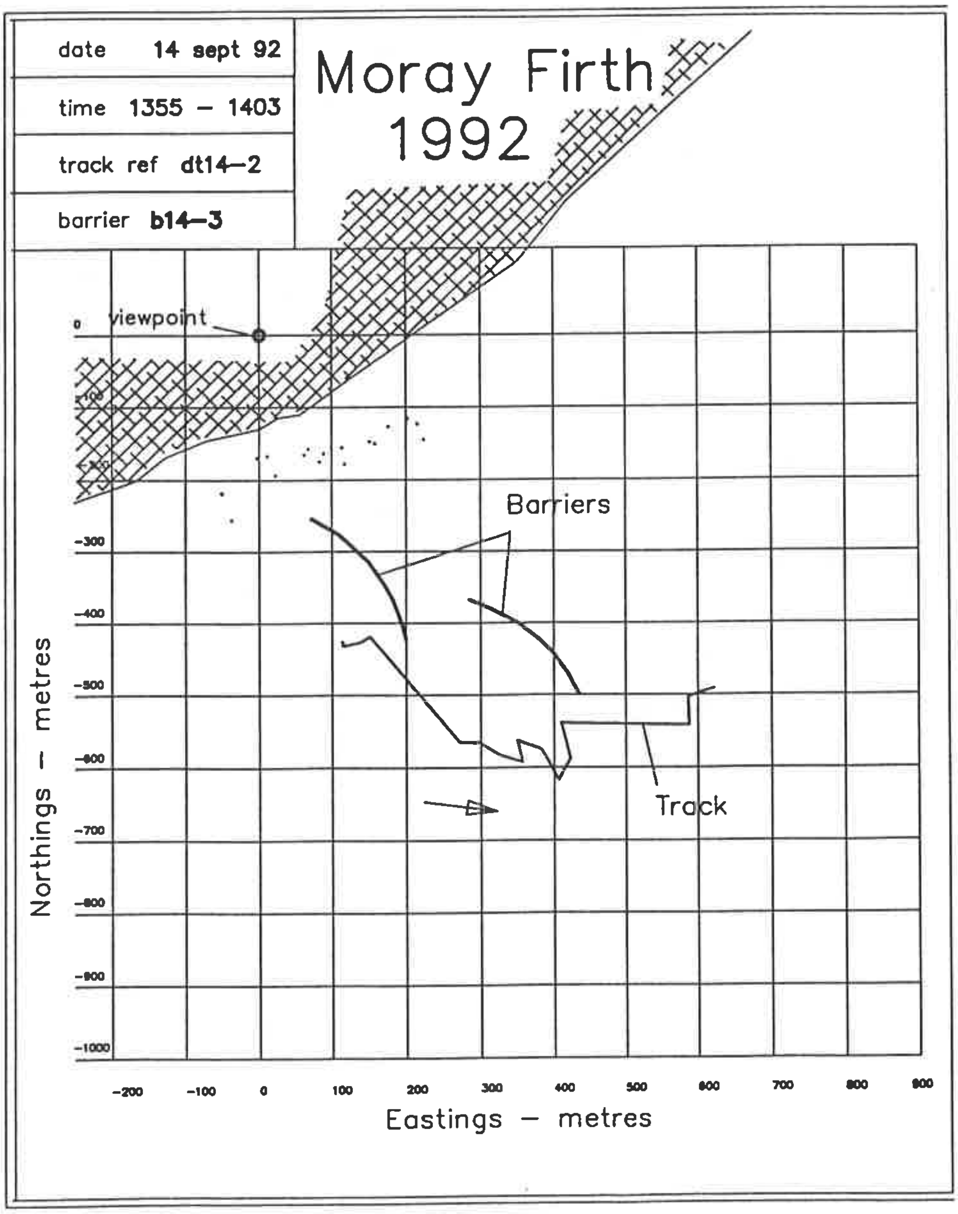

Figure 2
Typical Dolphin Track

UNDERWATER ACOUSTIC TRACKING

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INTRODUCTION One promising method for reducing cetacean by-catches involves the attachment of passive acoustic reflectors to nets (Goodson and Datta, 1992). To study the effectiveness of these reflectors, knowledge of the behaviour of cetaceans in the vicinity of nets is needed. This paper describes a system under development which is designed to track cetaceans underwater by triangulating their sonar clicks. The research aims are to track bottle-nosed dolphins, but the system can be used to track any other species of cetacean that is echolocating. The technique is to detect the clicks on three hydrophones, measure the three differences in arrival times, and calculate the co-ordinates of an animal's position using a computer programmed with a novel algorithm (Hardman and Woodward, 1984). The complete underwater acoustic tracking system is shown in Figure 1.

PRINCIPLES OF POSITION FIXING The algorithm assumes that the exact locations of the three hydrophones are known. It converts the relative arrival times of a click at the three hydrophones, H-1, H-2 and H-3, to the x- and y- co-ordinates of a dolphin's position. The arrival times at H-1 and H-3 are measured relative to its arrival time at H-2, giving two independent time differences t_{12} and t_{32}. These variables produce *two* (x,y) co-ordinates; this is because the determination of the y- co-ordinate involves a quadratic equation, giving two mathematically correct solutions, each with a corresponding value of x. Areas of valid dual solution for a typical hydrophone array are shown in Figure 2.

Only one of these solutions is the true location of the dolphin. One can often be eliminated by working out the time delays that both solutions would have produced, then comparing these with the real time delays originally used in the algorithm. Depending on the arrangement of the hydrophones, the second solution produces a different pair of time delays and can be eliminated. In other cases, both possible locations yield identical time delays which are equal to those measured. This leads to the concept of a 'ghost' solution which normally occurs when the source is close to one of the hydrophones, as shown in Figure 3.

The algorithm sets a maximum allowable speed of 10m/s, appropriate for a bottle-nosed dolphin, and the processing eliminates any calculated position which could not be reached from a previous position. Effectively, this sets a 'search circle' around the last known position; the radius of this circle will be the dolphin's maximum speed multiplied by the time since its last click, and its next position must be contained within this circle. This technique frequently eliminates the ghost solution.

Estimation of a position assumes that a dolphin's echolocating clicks are received by all three hydrophones. However, there remains the problem of determining which clicks received by H-2 corresponds to the clicks received by H-1 and H-3; this problem gives rise to potential ambiguities, particularly for high click rates. It can be shown that for a given click on H-2, the same click on H-1 is in an 'arrival time window' of

$$\frac{-d_{12}}{c} \leq t_{12} \leq \frac{d_{12}}{c} \text{ seconds}$$

where d_{12} is the distance between H-1 and H-2, typically 100m for a large array, and c is the speed of sound, assumed here to be 1500 m/s. This calculation gives a *total* arrival time window of about 70ms. On rare occasions, an echolocating dolphin may emit up to 1000 clicks per second, representing an inter-click period of 1 ms, so a given click on H-2 would correspond to one of possibly *seventy* clicks on H-1 and H-3.

This is a worst-case scenario and is unnecessarily pessimistic. The occurrence of high click rates only occurs when the dolphin homes in on a fish, whereas typical clicking during foraging is at an irregular rate of perhaps ten clicks per second. This gives a typical click interval of 20ms, leaving only three or four possible clicks on H-1 and H-3 to associate with the corresponding click on H-2, as shown in Figure 4.

From a known start position, the determination of subsequent positions is greatly simplified. A dolphin swimming in the general area of the array at typical speeds would cause clicks to be received on all three channels with time delays which do not change quickly. For any given click arriving at H-2, an expected arrival time window for the same click arriving at H-1 can be worked out from the known delays associated with the previous click and the time elapsed since it was emitted.

One significant factor affecting the performance of the system is that when echolocating close to a fish target, a dolphin tends to reduce its sonar power output. So despite emitting clicks at a higher rate, the peak power is reduced, thereby lowering the likelihood of clicks being detected by the hydrophones. Thus, there is likely to be a trade-off between target click rate and detectable range.

DESIGN OF THE SYSTEM The system has been designed in a modular form to allow upgrading of its components separately as its development continues. The present arrangement takes its data from an instrumentation tape recorder. Clicks from each of the three channels shown in Figure 1 are high pass filtered to attenuate extraneous frequencies below 5 kHz, then amplified and passed to a 'click detector' which produces a short rectangular pulse for any click significantly above the noise level. These pulses are then fed to a digital data logger which effectively time-stamps each pulse with its arrival time. A series of pulses generates a stream of arrival times, which are passed to an IBM-compatible computer via a commercial data acquisition 'card'. From the computed data, a dolphin's track can be plotted; this is currently displayed on a computer monitor, but producing hard copy plots is a simple operation. At present, it is uncertain whether the system will be capable of tracking in real time or whether it will be required to store the signals and perform calculations later.

At sea, it would be convenient to attach the hydrophone array to a fishing net, but this would appear to rule out a large triangular array since only two hydrophones can be conveniently mounted on the net itself. If not securely fixed relative to each other, the hydrophones will drift, resulting in position fixing errors. Some simulations have been carried out on a small equilateral triangular array with a side length of about 1 m. One advantage of having such a small array is that it can be made very rigid, allowing accurate measurement of positions. Another advantage is that the 'arrival time windows' of the algorithm are proportional to the size of the array: small arrays mean quicker and easier detection of clicks. A third advantage is that the ghosting problem is less severe, since the dolphin can usually be assumed to be outside the array triangle and therefore the real location of the dolphin can be easily distinguished from the ghost position. However, simulations with a very small array showed up a notable problem. The extremely small time delays that result mean that very precise calculations need to be carried out. The normal precision used has revealed that the array acts like a directional hydrophone, in that the direction of the source is evaluated satisfactorily but the range is difficult to measure accurately, especially if more than about 50 metres.

If the logistical problems of fixing the hydrophones can be overcome, perhaps by mounting them on the sea bed near a static net, a large array can be used. The advantage of this arrangement is that precise target location is possible, although initial acquisition of clicks is more difficult. The disadvantage is that hydrophones are so widely spaced that clicks may be detected on only one or two channels. The software is designed to ignore the received clicks in this situation. In the event of more than one animal echolocating simultaneously, a large array is likely to give rise to incorrect position fixes, so a small array is more suitable in this situation.

One possibility which has been attempted is to use a straight line array, with all three hydrophones in line. It is clear that this arrangement will *always* give a symmetrical ghost position. Only the physical location of the hydrophones would reveal the correct source: during dolphinarium tests, the array was mounted along a wall, which resulted in a mirror image of the dolphin's position reflected in the wall. Such an arrangement, on a larger scale, would be convenient for mounting on a net at sea.

CONCLUSIONS The system under development should be capable of tracking dolphins in relation to a fixed three-hydrophone array and enabling their reactions to obstructions such as nets to be observed while they are swimming underwater. The system should also be suitable for tracking pingers carried by divers or submersible vehicles. The software-based tracking system is in theory capable of tracking any number of acoustic sources which the hardware can detect, although there are practical limits to the rate at which data can be transferred from the timing and interface electronics to the computer. The system should provide a practical method of monitoring the effectiveness of passive acoustic net reflectors which are currently being tested to enhance net detectability and reduce by-catches.

ACKNOWLEDGEMENTS It is a pleasure to record our gratitude to Peter Bloom and his staff at the UK Dolphin Centre at Flamingo Land, Yorkshirs, and to our colleague David Goodson. Financial support from the European Commission is also acknowledged.

REFERENCES

Goodson, A.D. and Datta, S. 1992. Dolphin sonar signal analysis: factors affecting fishing net detection. Pp.179-183. In *European Research on Cetaceans - 6*. (Ed. P.G.H.Evans). Proc. 6th Ann. Conf. ECS, San Remo, 20-22 Feb 1992. European Cetacean Society, Cambridge. 254 pp.

Hardman, P.A. and Woodward, B. 1984. Underwater location fixing by a diver-operated acoustic telemetry system; Acoustica, 55, (1) 34-44.

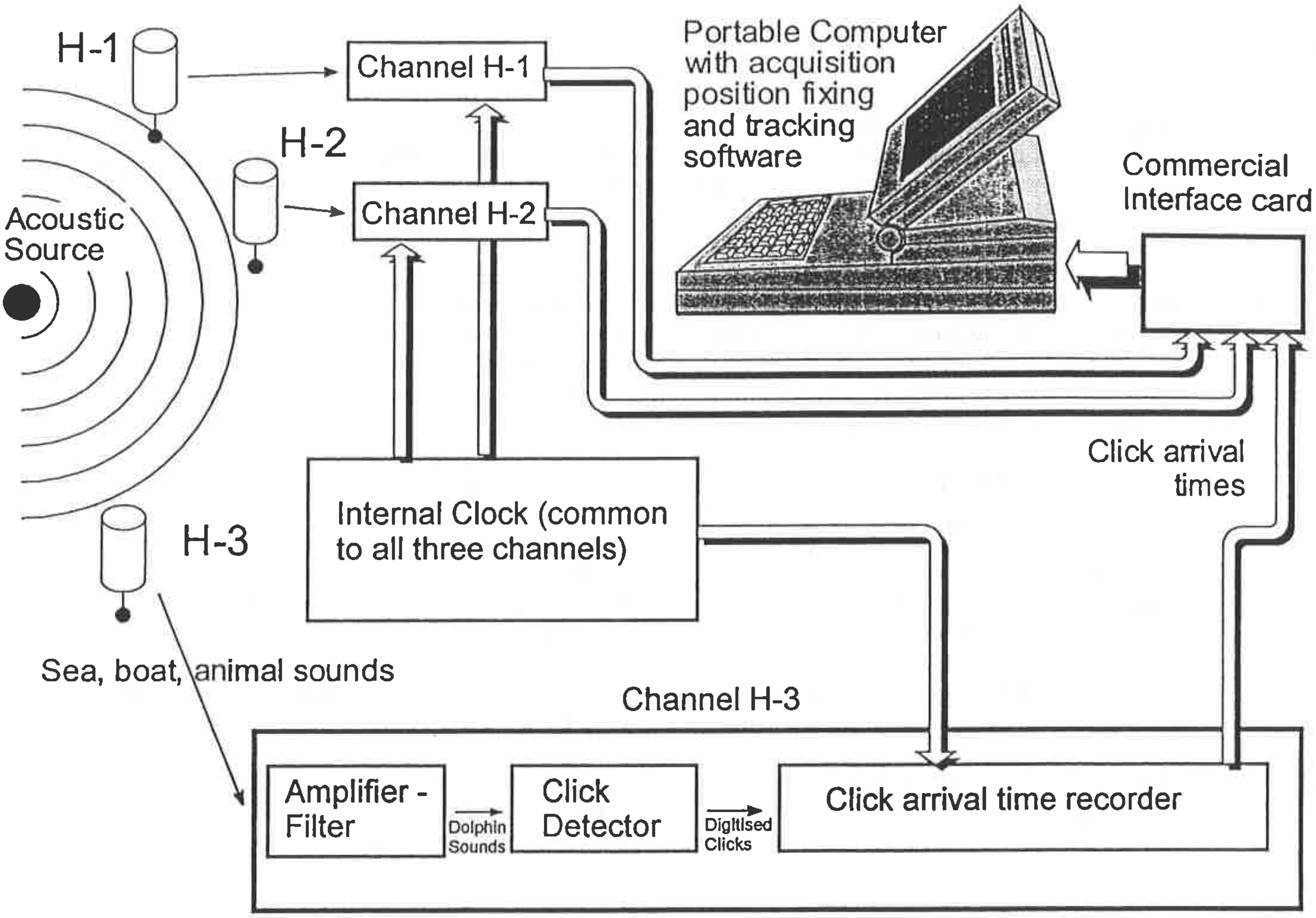

Fig. 1 Underwater acoustic tracking system

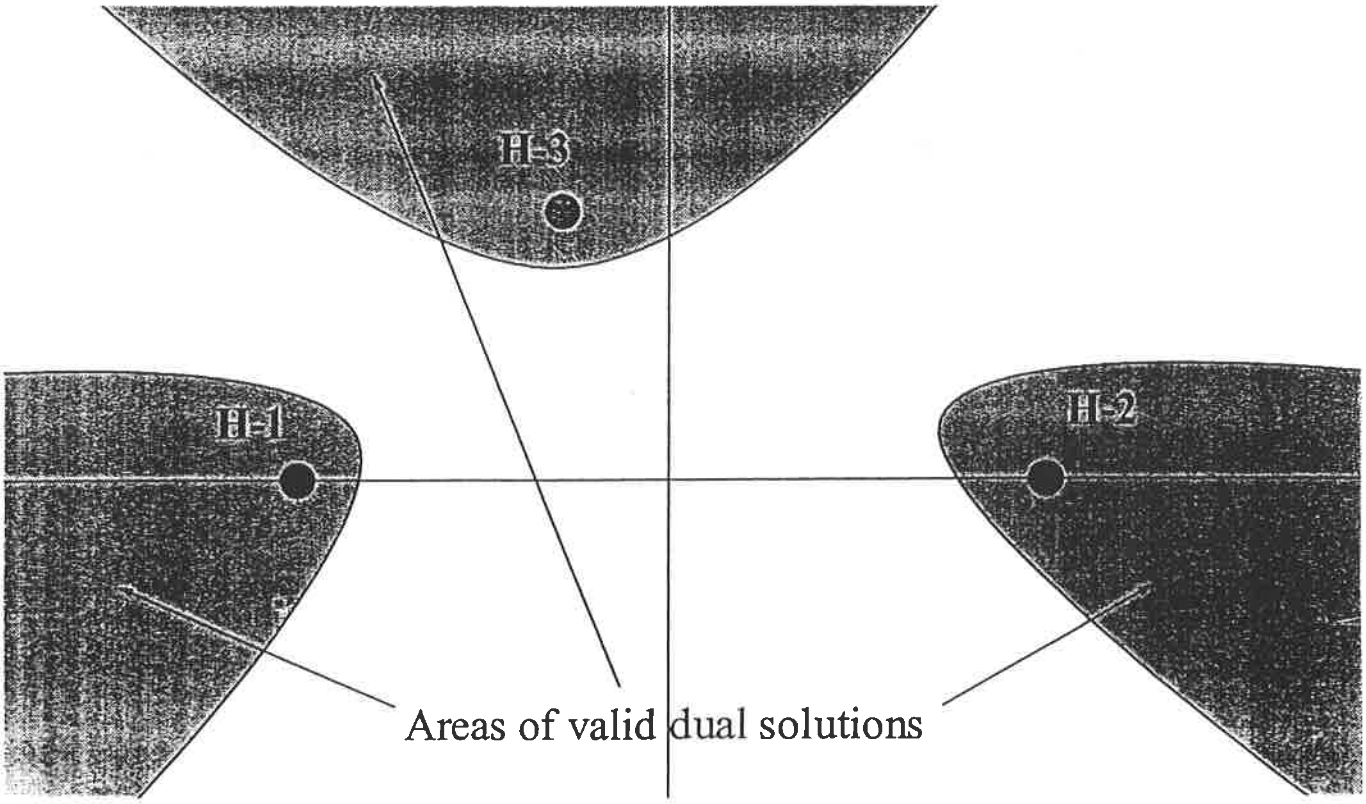

Fig. 2 Typical hydrophone deployment showing areas of valid dual solutions

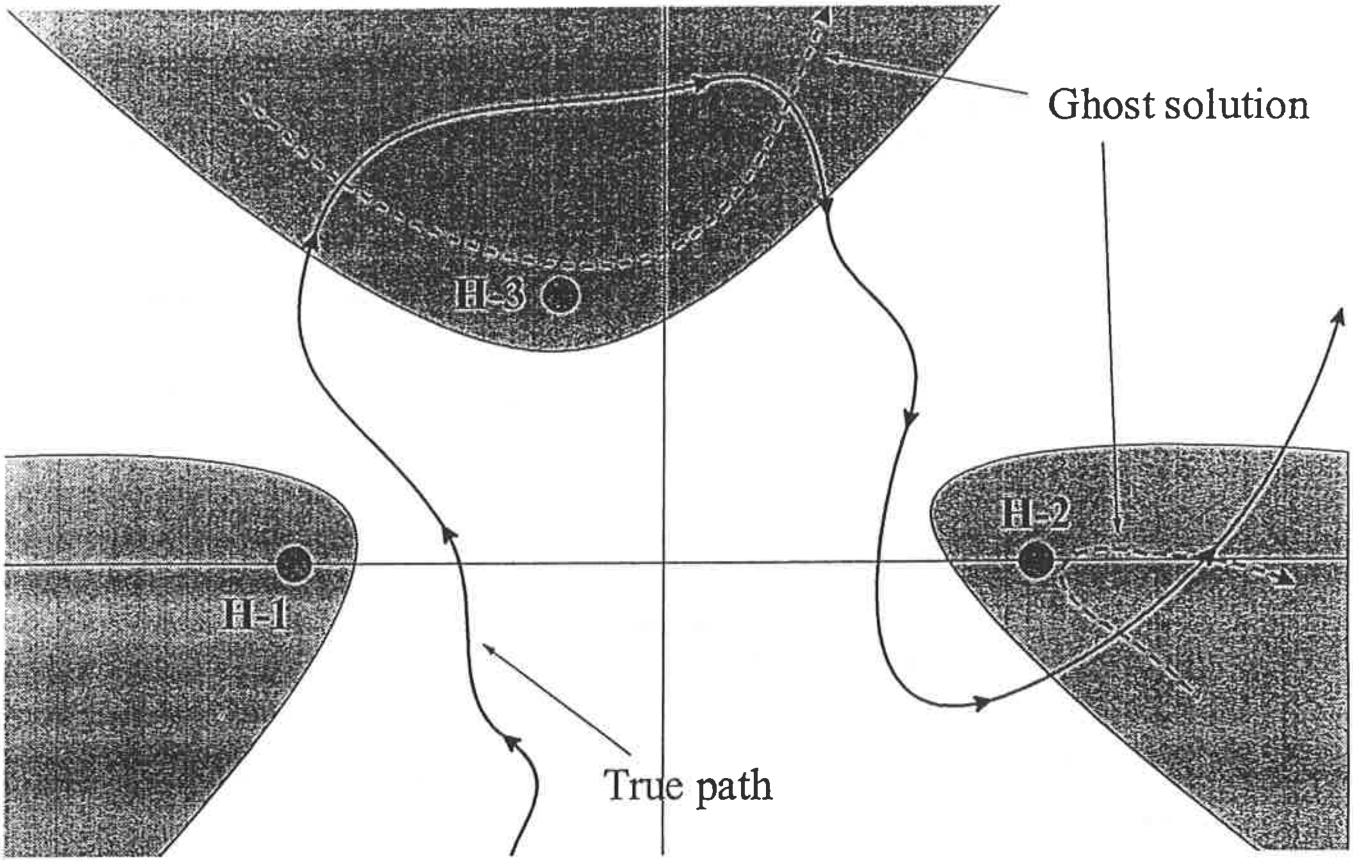

Fig. 3 Computed tracks, showing "ghost" solutions

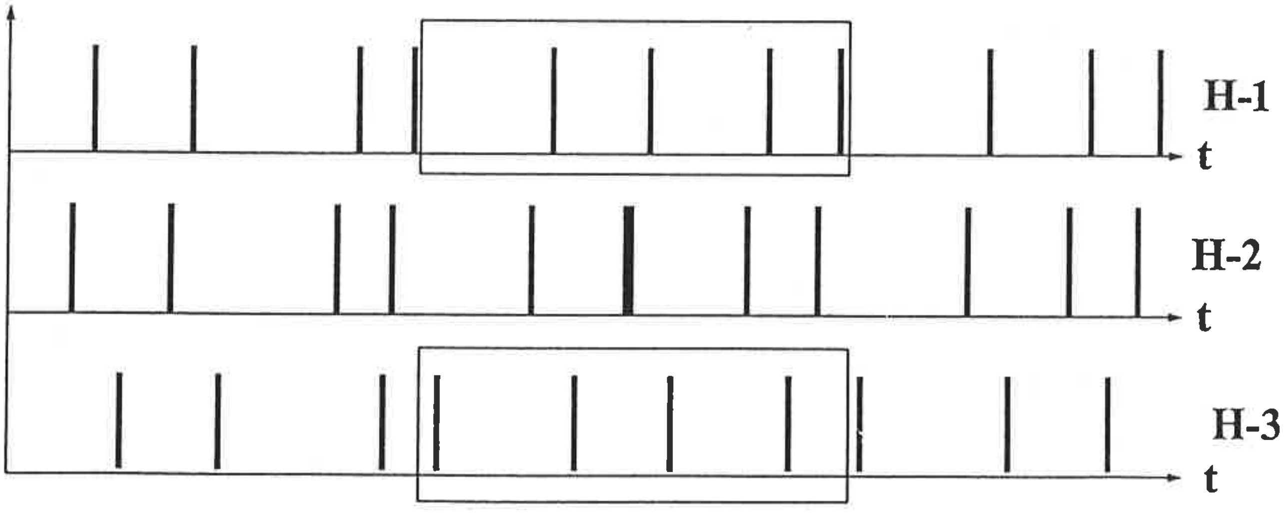

Fig. 4 Typical output from "click detector" on three channels

THE POTENTIAL FOR THE USE OF PASSIVE ACOUSTIC TECHNIQUES IN FIELD STUDIES AND SURVEYS OF PORPOISE POPULATIONS.

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INTRODUCTION Harbour porpoises (*Phocoena phocoena*) are believed to be declining or endangered in the North Sea, the Baltic, the Black Sea, and off the Atlantic coast of USA and Canada. Fisheries bycatch and pollution are two likely causes of this. There is a pressing need for intensive survey work in co-ordination with other activities to improve the conservation and welfare of this species.

Harbour porpoises are shy undemonstrative creatures which are extremely difficult to spot at sea. Visual surveys can only be attempted in the calmest conditions (which are rare in northern Europe) and even then they are problematical. (During this study there were occasions in flat calm waters when we knew that porpoises were within 50m, and could hear them breathing, but could not reliably spot them).

Acoustic techniques for censusing cetaceans often offer advantages over visual methods, for example:
- the acoustic range of vocalisations is more predictable than visual range.
- acoustic range is less affected by meteorological conditions than visual range.
- often (particularly when small research vessels are used) acoustic range is superior to visual range.
- acoustic surveys are less onerous than visual surveys so smaller survey teams can be used.
- acoustic surveys can be conducted 24 hours a day. Both day and night.
- there is a greater potential for automation of data collection and detection, reducing the scope for inter-observer biases.
- Generally, acoustic surveys are well suited to completion from small platforms of opportunity. This can greatly reduce the cost of surveys.

With these considerations in mind, we have been investigating methods for censusing porpoise populations acoustically

FIELD TESTS Using a towed, broad-band hydrophone system and the harbour porpoise click detector described in our earlier paper, we estimate that harbour porpoises can be reliably detected acoustically at ranges out to 400m (farther than we could reliably sight them from "Song of the Whale"). [These estimates are based on combined visual and acoustic field observations].

The same equipment was used during joint visual and acoustic searches for cetaceans in the Moray Firth. A team of 3-4 observers kept watch from the deck of "Song of the Whale" and from the crow's nest (10m), while a single worker monitored hydrophones below decks. The two teams were on the same boat but worked independently and did not share information on sightings. Porpoises were detected acoustically before being seen on 18 out of 19 acoustic encounters. On 10 out of 19 encounters, porpoises were not seen at all. Porpoises were never seen and not heard (Fig. 1).

FURTHER WORK We are encouraged by the results of our preliminary work and will continue the development of techniques for surveying harbour porpoises during 1993. Emphasis will be placed on developing a largely autonomous apparatus using specially built detection circuits and a portable computer to detect and log the presence of harbour porpoise vocalisations. Such equipment could be fitted to a wide variety of platforms of opportunity, such as yachts and ferries, to allow harbour porpoise abundance to be measured over large areas at an affordable price. Acoustic techniques can be complementary to visual ones and we envisage them often being used alongside each other during daylight hours.

The development of directional equipment, probably involving timing the arrival of clicks at hydrophones in small arrays, will also be investigated.

Simple acoustic equipment like this should be a useful tool in behavioural studies of harbour porpoises. It may also have a role in understanding and alleviating the problem of entanglement of porpoises in fishing gear.

The same approach should also prove useful with some other species. The vaquita and *Cephalorhynchus* sp., whose vocalisations are very similar to those of the harbour porpoises, are obvious candidates.

ACKNOWLEDGEMENTS This work was funded by the International Fund for Animal Welfare with the help of a grant from the European Commission through the Eurogroup for Animal Welfare. Surveys in the Moray Firth were conducted in conjunction with the University Field Station of Aberdeen University.

The Racal 141 tape recorder was donated by Racal and the high frequency hydrophone by Marconi Underwater Systems, to Dr Peter Evans, and loaned to this project by him.

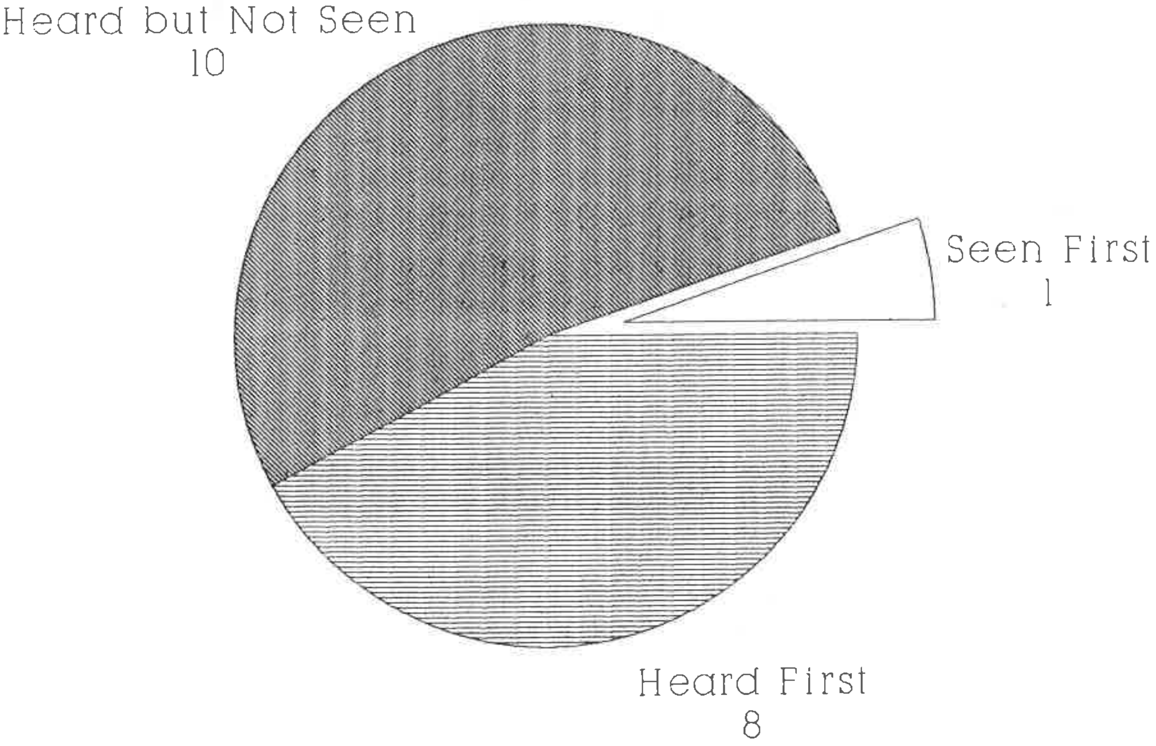

Fig. 1 Results of joint acoustic and visual search for porpoises

COLLECTION AND ANALYSIS OF OPPORTUNISTIC CETACEAN SIGHTING DATA

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There are numerous difficulties in attempting to estimate whale density by visual survey from small boats, due to the low speed and short detection range of the vessel and to the behaviour of the whales, which may surface only briefly. To minimise these difficulties it is usually necessary to adopt a strict survey protocol which requires the vessel to follow a fixed track and may involve complex data-collection procedures. We have designed a method of analysis suitable for data obtained opportunistically from small vessels whose primary purpose may not be whale survey. This was used by IFAW during summer 1992 to study the distribution of minke whales (*Balaenoptera acutorostrata*) around Mull. The aim is to show the spatial distribution of whales in an area of interest by dividing the area into cells and calculating an index of abundance for each cell. The index is based on a surfacing count which is made for a fixed period (30 mins) each time whales are seen. The distance covered on search effort within each cell is also required.

We have developed the program "Logger" to enable suitable data to be collected. The program runs on a portable PC and is linked to the vessel's GPS satellite navigation system. The program continuously monitors the vessel's position, which is shown superimposed on a map of the area. Data on environmental conditions, effort status and sightings of various species can be entered at any time, and the program issues reminders when appropriate. The surfacing data can be entered in real time using key presses to represent surfacings. Data is stored in a popular database format, which allows flexibility in manipulating the data and selecting subsets for analysis. A companion program reads the data stored by Logger and calculates the index of abundance for any specified subset of the data, displaying the result as a shaded overlay on a map of the area.

SATELLITE TELEMETRY AND MARINE MAMMALS

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Satellite telemetry, using the Argos System, provides a powerful technique for remotely logging positional and behavioural data from transmitters attached to free-ranging animals.

SMRU has been involved in the development of Argos compatible transmitters for marine mammals for many years. Progress was slow due to the difficulty of testing the design for the rugged operating environment and the near impossibility of recovering failed units for investigation. In the last three years, however, we have produced and deployed more than sixty units which have returned large amounts of data over periods of deployment exceeding two hundred and fifty days in some cases.

These transmitters have been successfully deployed on seven species of pinniped and cetaceans. As well as tracking the animals movements the transmitters contain a small computer which stores depth and velocity data and relays it via the Argos System in a processed and compressed form. This has given us a unique insight into the behaviour of the animals in relation to their physical environment.

The poster shows some of the results from satellite tracking studies on beluga whales (*Delphinapterus leucas*), grey seals (*Halichoerus grypus*) and southern elephant seals (*Mirounga leonina*).

SKIN BIOPSIES IN CETACEANS: A NON-DESTRUCTIVE METHOD FOR BIOMARKER STUDIES

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INTRODUCTION In the last century, cetaceans in all parts of the world have been subjected to heavy anthropogenic pressure. In the 1990's, mass stranding of cetaceans, particularly dolphins, has occurred along the coasts of Italy and Spain. Several specimens of striped dolphin (*Stenella coeruleoalba*) have died from viral diseases. Nobody has furnished evidence of the direct involvement of pollution in the stranding episodes, but hypotheses have been made on the role of PCB's in immune suppression (Brouwer *et al.*, 1986), and in reproductive impairment (Cummins, 1988). In Mediterranean cetaceans, it is therefore crucial to know contaminant levels and to identify toxicological responses. Data have recently been collected on levels of pollutants in the organs and tissues of stranded cetaceans (Borrell and Aguilar, 1990). Such data alone are unable to define the "health" of these species unless accompanied by studies on biological responses to the xenobiotic compounds. Another important point regards the need to check not only stranded animals but also living specimens without killing or disturbance. For these reasons, the development of a "non-destructive" technique to evaluate the biochemical responses to xenobiotic compounds (such as organochlorines), using the biomarker approach, is strongly recommended.

In eco-toxicological studies in the last 15 years, biomarkers, commonly defined as "molecular, biochemical and cellular changes caused by pollutant chemicals which are measurable in biological media such as cells, tissues and body fluids", have provided an "early warning sign" of the health of natural populations of vertebrates, in the form of an "integrated" sign, in time and space, of the chemical stress caused by a mixture of pollutants (McCarthy and Shugart, 1990).

In this study, we propose the use of a conventional biomarker, the mixed function oxidase activity, in a "non-destructive" way, evaluating the benzo(a)pyrene mono-oxygenase activity (BPMO) in free-ranging cetacean skin biopsy specimens collected by a non-invasive method. The theoretical assumption of this work was knowledge of the presence of MFO activity in mammal skin (Bickers *et al.*, 1982). Experimental confirmation that MFO activities (AHH and 7-EC) are induced in the whole skin of neonatal rats by topical application of Arochlor 1254 (Bickers *et al.*, 1982) suggests that this method might be used for the non-destructive testing of marine mammals.

MATERIALS AND METHODS Skin biopsies of striped dolphins (n=7) and fin whales (*Balaenoptera physalus*) (n=9) were collected by a non-invasive sampling method (dart) in the northern Tyrrenian Sea during the summer of 1991. The skin samples, weighing about 0.5g, were divided into two different aliqouts. The epidermal tissue was stored in liquid nitrogen and later processed in the lab for BPMO analysis. The subcutaneous blubber was stored at -20°C and processed for chlorinated hydrocarbon analysis. The size of samples (between 0.200g and 0.002g) did not allow isolation of the microsomal fractions. BPMO activity was detected in the whole tissue. Since the connective tissue was very tough, the epidermis was homogenised in 1.15% KCl buffer at pH 7.5 by thermal shock, and separated by freezing in liquid N_2, and pulverising in a potter apparatus with ultrasound. BPMO activity was assessed using the incubation mixture proposed by Kurelek *et al.* (1977), incubating each sample (plus the blanks) in a warming shaking bath for 2 hrs at 37°C. The activity was expressed in (arbitary units of fluorescence) AUF/h/g tissue. For analysis of chlorinated hydrocarbons, samples were freeze-dried and extracted in Soxhlet with n-hexane; the analytical method used was high resolution capillary gas chromatography (Focardi *et al.*, 1988). Statistics were performed on a PC computer using statgraphic software (Statgraphic Corporation). Differences between specimens were calculated by the non-parametric Mann-Whitney test.

RESULTS AND DISCUSSION The main result of this preliminary study concerns the detection of BPMO activity in cetacean skin biopsy samples, previously discussed by Fossi *et al.* in 1992. Although MFO activity is several times lower than BPMO activity, detected in liver samples of striped dolphins from Japan by Watanabe *et al.* (1989), it is easily detectable by conventional enzyme methods in whole tissue instead of the microsomal fraction. Moreover, the incubation time required is longer. Figure 1 reports the geometric mean values of BPMO activities in the skin samples of the two cetacean species, together with mean values of PCBs and DDTs. BPMO activity in striped dolphins is four times higher than in fin whales ($p<0.020$); this difference in enzyme activity btween the two species may be explained as follows. As reported by Focardi *et al.* (1992) in a previous paper, the two species differ dramatically in levels of organochlorines in subcutaneous blubber. In the present data, the level of PCBs and DDTs are 12 times ($p<0.0005$) and 9 times ($p<0.0005$) higher respectively in the striped dolphin than in the fin whale.

The difference in the organochlorine bioaccumulation processes between the two species is commonly related to the different position in the marine food chain. In this case, the striped dolphin may be regarded as a terminal consumer that preys mainly on fish and squid with an average PCB content of about 0.080 ppm (Focardi *et al.*, 1992); the fin whale occupies a lower trophic level feeding on plankton with an average level of PCBs 5-10 times lower than the food of dolphins. The PCB levels of prey are reflected by the levels of PCBs in the skin biopsy specimens.

According to the well known capacity of organochlorines to induce MFO activity in fish, bird and mammal liver (Clarke, 1986), the main explanation of this interspecific difference in the enzyme responses may be found in the chlorinated hydrocarbon induction processs. The phenomenon of MFO induction in mammal skin is well documented in rats after cutaneous administration of PCBs (Bickers *et al.*, 1982). Plotting the sum of organochlorines with BPMO activity, we find two species-specific sets of points showing an overall trend of increased enzyme activity with increased levels of contaminants (Fig. 2). The present study suggests that biomarkers, together with the results of chemical residue analysis, can be used in a combined approach for evaluating the toxic risk of populations of marine mammals. The development and perfecting of the analytical methods together with the availability of a larger number of samples will lead to better biochemical characterisation of the mono-oxygenase system in cetacean skin, shedding light on the relationship beween chemical stress and biochemical response (biomarker).

REFERENCES

Bickers, D.R., Dutta-Choudhury, T. and Mukhtar, H. 1982. Epidermis: a site of drug metabolism in neonatal rat skin. Mol. Pharmacol., 21: 239-247.

Borrell,A. and Aguilar, A. 1990. Loss of organochlorine compounds in the tissues of a decomposing stranded dolphin. Bull. Environ. Contam. Toxicol., 45: 46-53.

Brouwer, A., van den Berg, K.J., Blaner, W.S. and Goodman, D.S. 1986. Transthyretin (prealbumin) binding of PCBs, a model for the mechanism of interference with vitamin A and thyroid hormone metabolism. Chemosphere, 15 (9-12): 1699-1706.

Clarke, J.U. 1986. Structure-activity relationships in PCBs: use of principal components analysis to predict inducers of mixed-function oxidase activity. Chemosphere, 15(3): 275-287.

Cummins, J..E. 1988. Extinction: the PCB threat to marine mammals. The Ecologist, 18(6): 193-195,

Focardi, S., Leonzio, C. and Fossi, C. 1988. Variations in polychlorinated biphenyl congener composition in eggs of Mediterranean water birds in relation to their position in the food chain. Environ. Pollut., 52: 243-255.

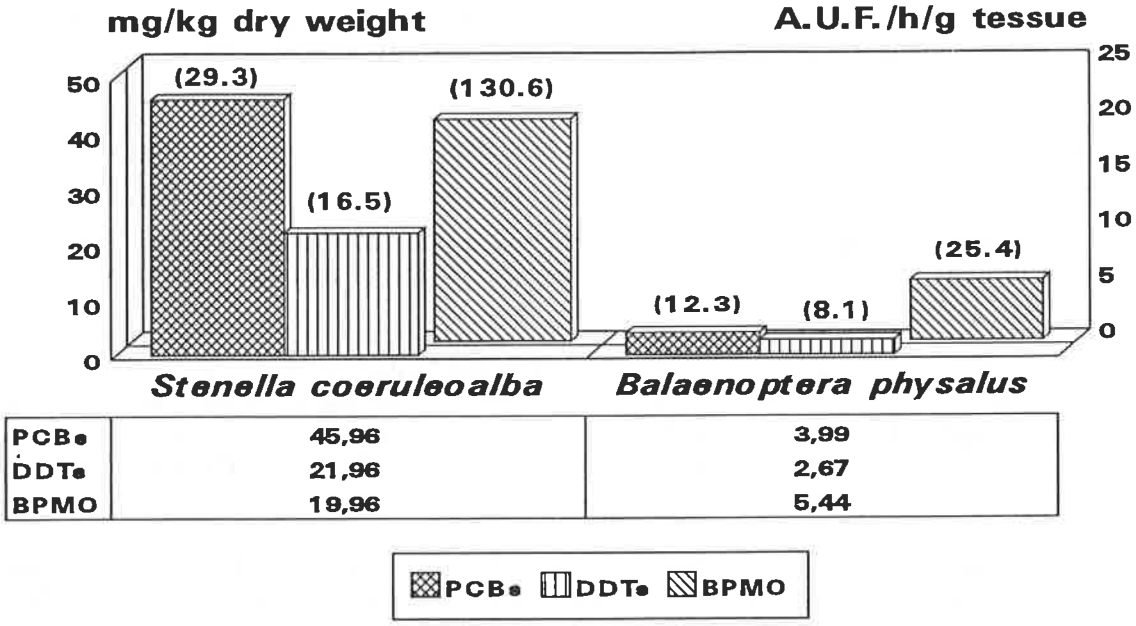
Focardi, S., Marsili, L., Leonzio, C., Zanardelli, M. and Notarbartolo di Sciara, G. 1992. Organochlorines and trace elements in subcutaneous blubber of *Balaenoptera physalus* and *Stenella coeruleoalba*. Pp. 230-233. In *European Research on Cetaceans - 6* (Ed. P.G.H. Evans). Proc. 6th Ann. Conf. ECS, San Remo, 20-22 Feb. 1992. European Cetacean Society, Cambridge. 254pp.

Fossi, M.C., Marsili, L., Leonzio, C., Notarbartolo di Sciara, G., Zanardelli, M. and Focardi, S. 1992. The use of non-destructive biomarkers in Mediterranean cetaceans: preliminary data on MFO activity in skin biopsy. Mar. Pollut. Bull., 14(9): 459-461.

McCarthy, J.F. and Shugart, L.R. 1980. *Biomarkers of environmental contamination.* Lewis Publishers, Florida. 457 pp.

Kurelec, B., Britvic, S., Rijavec, M., Miller, W.E.G. and Zahn, R.K. 1977. Benzo(a)pyrene monooxygenase induction in marine fish - molecular response to oil pollution. Mar. Biol., 44: 211-216.

Watanabe, S., Shimada, T., Nakamura, S., Nishiyama, N., Yamashita, N., Tanabe, S. and Tatsukawa R. 1989. Specific profile of liver microsomal cytochrome P-450 in dolphins and whales. Mar. Environ. Res., 27: 51-65.



	Stenella coeruleoalba	Balaenoptera physalus
PCBs	45,96	3,99
DDTs	21,96	2,67
BPMO	19,96	5,44

Fig. 1 BPMO activities and organochlorine levels in skin biopsies of Mediterranean striped dolphin (n = 7) and fin whale (n = 9). Geometric mean and range in brackets.

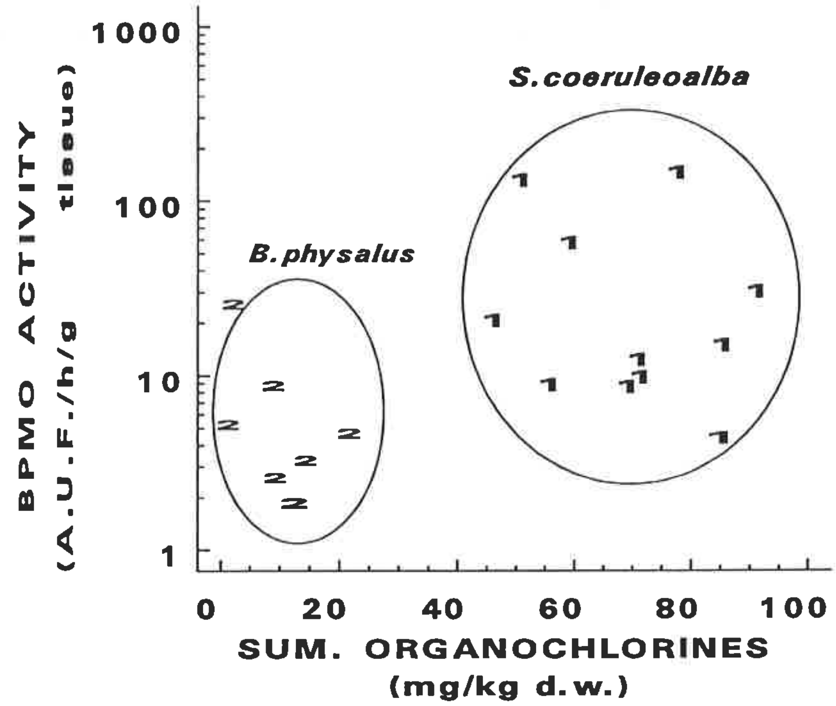


Fig. 2 Plot of total organochlorines with BPMO activity in skin biopsies of (1) striped dolphin and (2) fin whale

NEW AGREEMENT ON THE CONSERVATION OF SMALL CETACEANS OF THE BALTIC AND NORTH SEAS

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In March 1992, the final text of a new international Agreement was drawn up and made available for signing at the New York headquarters of the United Nations. This Agreement concerns the Conservation of Small Cetaceans of the Baltic and North Seas, and was concluded under the auspices of the 1979 Bonn Convention on the Conservation of Migratory Species of Wild Animals. The Interim Secretariat for this agreement has been set up at the Sea Mammal Research Unit in Cambridge, commencing in June 1992 under Dr. Christina Lockyer, a cetacean specialist, initially under contract to the Department of the Environment (DoE).

This agreement covers all toothed whales, dolphins and porpoises (except the sperm whale, *Physeter macrocephalous)* and aims to manage and conserve their habitat, provide surveys and research, fully utilise by-catches and strandings for research, establish legislation prohibiting intentional kill, encourage research and technology for reducing incidental catches of cetaceans, and provide information and education to the public, including the fishing industry. Items already identified as priorities include potential impacts of pollution, noise, and fishing operations on cetaceans. Sweden, Germany, United Kingdom, Netherlands, Denmark, Belgium (all Range States) and the European Economic Community (EEC) have signed, and full ratification of the Agreement by the Range States is expected soon. The Agreement should be in force by mid-1993, now that six Range States (the number necessary for the Agreement to come into force) have signed. The text of a similar agreement for the Mediterranean Range States is in the final stages of preparation.

CETACEAN CONSERVATION IN THE UK - MORE RESEARCH OR MORE ACTION?

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INTRODUCTION In March 1992, an international agreement concerning the Conservation of Small Cetaceans of the Baltic and North Seas was finalised under the 1979 Bonn Convention on the Conservation of Migratory Species of Wild Animals. The agreement commits the UK Government to take measures to protect small cetaceans as well as to undertake research to further understand their ecology and the threats they face. The Government has indicated that it sees this commitment as extending to all British waters. British waters are home to many species of cetacean including bottle-nosed dolphins (*Tursiops truncatus*) and harbour porpoises (*Phocoena phocoena*). Both are listed species on Appendix 2 of the Bonn Convention which highlights their "unfavourable conservation status". On 6th November 1992 the Environment Minister Lord Strathclyde (Strathclyde, 1992) said: "The Government is determined to support our commitment to take practical measures to protect dolphins and other small whales from the threats they face in the marine environment." The following examples show that the UK Government has neither taken active steps to protect whales and dolphins nor instituted a research programme which will address the fundamental questions about status which need to be answered.

THREATS FACING SMALL CETACEANS IN BRITISH WATERS The potential threats to small cetaceans include pollution, fisheries by-catch and disturbance. Action to stop these threats should be one of the priorities of cetacean conservation. Research to further characterise the threats is important but must not be used as an excuse to delay action. Threats must not be viewed in isolation as more than one may be having an impact on a population at any one time.

Pollution The threat to the health of marine mammals from pollutants such as PCBs and other organochlorines is well recognised. One of the highest levels of organochlorines ever recorded was found in a bottlenose dolphin calf in Cardigan Bay, Wales in 1989 (Morris *et al.*, 1989). PCBs may impair immune function and reproduction and render a population less able to combat disease.

Only two or three organochlorines are monitored in industrial discharges and despite their toxicity and persistence are still allowed to be released. Many of the other chemicals which are discharged are uncharacterised and their effects unknown. There is also an undetermined run-off from landfill sites and agricultural practices and the aerial route of contamination is not considered. The UK has stopped its funding of contaminant analyses of cetaceans after one year.

Fisheries by-catch There is an unquantified accidental take of small cetaceans in fishing gear with harbour porpoises and common dolphins (*Delphinus delphis*) being the species most often caught (Northridge, 1988). To deal with the problem, it is important to identify which fishery is responsible. The Ministry of Agriculture Fisheries and Food (MAFF) run a voluntary recording scheme which is now acknowledged to have failed. In the early months of 1992, an unusually large number of common dolphins were found stranded on the Cornish coast. Post-mortem examination indicated that the animals had probably been drowned in fishing gear (Kuiken, 1992). One year on, we are no closer to knowing which fishery was involved. The EC have funded a voluntary observer scheme in Cornwall and Ireland but MAFF seem to be at a loss over what to do. It is difficult not to conclude that they are content to allow dolphins to be killed, arguing that they do not know what fisheries are at fault but taking no action to find out.

Disturbance The effects of human disturbance on cetaceans are poorly understood. There may be periods or locations where disturbance could have significant effects, such as at mating, calving or in nursery areas. Oil and gas operations bring the threat of acoustic disturbance, pollution from drilling muds, increased activity in the area and the ever present threat of an oil spill.

In 1992, the UK Government announced the 14th round of offshore licenses for oil and gas exploration. The areas being offered include many of importance for marine and other wildlife. Among these are Cardigan Bay and the Moray Firth which are the habitats of two UK resident groups of bottlenose dolphins. Other small cetaceans use these areas, including harbour porpoises and Risso's dolphins (*Grampus griseus*). Between March and October 1992, there were over 40 sightings of small cetaceans including bottle-nosed dolphins, harbour porpoises and Risso's dolphins at Bardsey Island in Cardigan Bay (Megan Morgan-Jenks, pers. comm.) only a few kilometres from the site of Hamilton Oil's exploratory drilling rig, licensed in the 12th Round against the advice of the Government's official conservation body (the Joint Nature Conservancy Council). In the wake of the Braer oil spill, the Government's determination to exploit such areas does not sit easily with their stated commitment to the conservation of whales and dolphins.

DISTRIBUTION, ABUNDANCE AND STATUS To be able to understand the ecology of cetaceans, there needs to be research on their distribution, abundance and status. Cetacean sightings are the main means by which distribution in British waters is assessed. Although they give an idea of the distribution of species in coastal waters, coverage is not uniform and they can only give information on abundance for very limited areas.

Since there have been few studies determining actual abundance, there is little information on sizes of UK cetacean populations. Reliable population estimates need an investment in dedicated ship and aerial surveys and the use of photo-identification techniques. The UK's contribution to the survey of harbour porpoises and other cetaceans in the North Sea is welcome and long overdue. However, the £110,00 to be spent over three years is not large in research terms and must be followed by a longterm commitment.

To understand what is happening to populations over time (i.e. their status) there must be support for a longterm effort to study populations, determine their size, distribution and stock identity. One scientist (Thompson, 1992) has recently concluded that there is insufficient data to assess the population status of any cetaceans occurring in Scottish waters and the same could apply to other UK cetaceans. Because there has been no strategic planning of research, vital areas of have been left without funding and research which has been funded is under-utilised.

CONCLUSIONS The UK Government should institute an Action Plan for Conservation and Research which cuts across Ministerial boundaries. This would include immediate action to address those threats which are well known, a research plan to identify and characterise other threats to small cetaceans and a longterm commitment to research to determine their status. The Action part of the Plan must be undertaken in a way which recognises that we cannot wait for proof of population declines before taking action and acknowledge that threats do not act in isolation. Unless the Government do this, their stated commitment to protect whales and dolphins will ring hollow and, undoubtedly, allow more animals to die. Scientists do not want to follow the demise of cetaceans in British waters.

REFERENCES

Kuiken, T. 1992. Post-mortem examination of the common dolphin (*Delphinus delphis*) die-off around Cornwall and Devon between 01/01/92 and 01/04/92. A preliminary report. Institute of Zoology, London. 19th June 1992.

Morris, R.L., Law, R.J., Allchin, C.R., Kelly, C.A. and Fileman, C.F. 1989 Metals and organochlorines in dolphins and porpoises of Cardigan Bay, West Wales. Mar. Poll. Bull., 20: 512-523.

Northridge, S. 1988. *Marine mammals and fisheries*. A study of conflicts with fishing gear in British waters. Wildlife Link, London.

Strathclyde, Lord, 1992. UK Government to Support North Sea Whale Survey. Department of the Environment News Release, 6th November 1992. Department of the Environment, 2 Marsham Street, London, SW1P 3EB, UK.

Thompson, P.M. 1992 The conservation of marine mammals in Scottish waters. Proc. Roy. Soc. Edin., 100B: 123-140.

ALL ANIMALS ARE EQUAL BUT SOME ARE CETACEANS: CONSERVATION AND CULTURE CONFLICT

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This presentation discusses some aspects of the cultural construction of cetaceans and how they have come to be key symbols in environmental debates. I analyse some of the rhetorical aspects of campaigns against whaling, focusing in particular on the use of metaphors. The classification by environmental groups of these animals as non-resources has consequences for the people who have looked at the hunting of marine mammals as a part of their subsistence and way of life. I argue that, in order to understand the conflict over the use of marine mammals, one has to consider the different views towards nature, eco-philosophies and indigenous idealogies in which animals gain meaning.

IS THERE ANY PROGRESS IN THE PROTECTION OF BLACK SEA CETACEANS?

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Nobody can say confidently about recent changes in the Black Sea dolphin populations. There are at present no national or regional Black Sea cetacean conservation programs. The majority of wild animal research was stopped before 1992 because of absence of funding.

Nevertheless, the investigation of strandings has continued. The numbers of dolphin carcasses found in 1991 (15) and in 1992 (10) on the Crimean coast were considerably less than in previous years (**1989** - 104; **1990** - 270) (Fig.1). The decline in number of stranded harbour porpoises was the most notable feature of recent observations (Fig. 2). It is very possible that the reduction of harbour porpoise (*Phocoena phocoena relicta*) strandings is a result of population decline caused by devastating epizootics in 1989 and 1990. In addition, those professional fishermen interviewed noted the decreasing frequency of encounters with dolphin schools.

Last year, we reviewed available data concerning the microbiology of Black Sea wild and captive cetaceans. 125 species of viruses, bacteria, microalgae and fungi were detected in these animals since the middle of the 1960's (Table 1). Some species are highly pathogenic for dolphins. The most infectious diseases are mixed-bacterial pneumonias and septicæmias caused by *Staphylococcus aureus* and members of the family *Enterobacteriaceae*. This is a corollary of intensive faecal pollution of coastal waters.

The retrospective analysis of helminthological data gave us one important conclusion: the nematode *Crassicauda sp.* is probably a new parasite for Black Sea cetaceans (Fig. 3)

Hundreds of post-mortem examinations made in the 1940's-60's did not reveal this worm. But last year's *Crassicauda sp.* is not a casual finding in the cranial air sinuses of Black Sea common dolphins (*Delphinus delphis*), bottle-nosed dolphins (*Tursiops truncatus*) and harbour porpoises. Crassicaudosis (osteolysis + local reactive meningitis) may be one of the leading mortality factors in the near future.

In 1992, we began to study heavy metal pollution of dolphin tissues. The levels of micro-elements in harbour porpoise teeth (the spectral analysis data) were recognised recently (Table 2).

So far, fresh scientific results are very limited. Legislative steps in protection of Black Sea dolphins are more encouraging: the new environmental protection laws in Russia and Ukraine, more strict state sanctions against poaching in Ukraine, and the new regulations of the Ukrainian Red Data Book are all to be welcomed. All three Black Sea dolphin species were recommended for inclusion in this book in 1992 (BREMA Laboratory's presentation).

At the same time, Ukraine has not yet signed either CITES or the Berne Convention. Only Ukraine has used marine mammals for military purposes in the Black Sea region. In 1992, there was also an export of performing bottle-nosed dolphins from Ukraine to Hungary, Chile and Israel.

Programme for the Conservation of Black Sea Marine Mammals: - Research projects of BREMA Laboratory

Estimation of abundance, distribution and migrations of dolphins and seals (including the systematic recordng of animals from coastal stations, ships, planes and satellites).

Investigation of cause of death, diseases and other injuries of stranded and incidentally killed wild animals (including pathomorphological, microbiological, virological, helminthological and toxicological studies).

Investigation of pathological conditions of live wild animals (including pathomorphological and toxicological studies of skin/blubber biopsies; microbiological studies of skin, blowhole and rectal samples; haematological, serological, immunological and biochemical studies of blood samples; helminthological studies of faeces; photo-idetification studies).

Pathological research on captive marine mammals (including all accessible methods) and elaboration of proper diagnostic, prophylactic and treatment techniques.

Comparative genetic analysis of Black Sea cetacean populations and their connection with other European *Tursiops truncatus, Delphinus delphis* and *Phocoena phocoena* populations.

Assembling the collections of cetological (osseous, cranial, etc.) material for museums of natural history.

If you have an interest in collaborating on any of these projects, please contact:
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Table 1 Micro-organisms of Black Sea dolphins

MICRO-ORGANISMS	CD		BD		HP
Viruses					
Influenza virus			1*		
Parainfluenza virus				1	
Virus of epidemic encephalitis			1		
Bacteria					
Leptospira interrogans			1		1
Pseudomonas spp.				12	1
Halobacterium sp.				1	
Flavobacterium spp.			5		
Alcaligenes spp.				3	
Escherichia coli				1	
Salmonella spp.			+		+
Citrobacter spp.		1		2	
Klebsiella spp.	1		1		
Enterobacter aerogenes			1		
Erwinia spp.				1	
Serratia spp.			1		2
Hafnia alvei				1	
Edwardsiella tarda				1	1
Proteus spp.				2	1
Prividencia rettgeri				1	
Morganell morganii			1		
Yersinia enterocolitica			1		1
Vibrio proteolyticus				1	
Photobacterium sp.				1	
Aeromonas spp.			2		1
Plesiomonas sp.			1		
Pasteurella multocida			1		
Actinobacillus spp.				2	
Zymomonas mobilis				1	
Chlamydia sp.			1		1
Mycoplasma spp.				2	
Micrococcus spp.				2	
Planococcus citreus				1	
Staphylococcus spp.		1		3	3
Streptococcus spp.				4	2
Sarcina sp.				1	
Bacillus spp.			15		
Listeria spp.				2	1
Erysipelothrix rhusiopathiae		1		1	1
Corynebacterum sp.					1
Actinomyces sp.			1		
Nocardia farcinica				1	
Byphtheroids				+	+
Algae					
Achnantes spp.			2		
Amphora spp.			2		
Berkeleya rutilans				1	
Fragillaria sp.			1		
Grammatophora marina				1	
Liomophora spp.				3	
Melosira moniliformis			1		
Navicula spp.			4		

Table 1 (cont.) Micro-organisms of Black Sea dolphins

Algae (cont.)	**CD**	**BD**		**HP**
Nitzschia spp.		4		
Pleurosigma rigidum		1		
Striatella unipunctata		1		
Synedra tabul,ata			1	
Ulothrix sp.			1	
Anabaena sp.		1		
Fungi				
Trichophyton sp.			1	
Alternaria sp.		1		1
Rhodotorula sp.		1		1
Cladosporium sp.			1	1
Mortierella sp.		1		1
Rombophytum sp.			1	
Hyphomyces destruens		1		
Candida spp.		4		5
Aspergillus fumigatus		1		
Penicillium sp.		1		
Phialopjhora sp.			1	
Species in total	1	122		28

CD - common dolphin
BD - bottle-nosed dolphins
HP - harbour porpoise
* quantity of detected species

Table 2 The micro-elements in the teeth of Black Sea harbour porpoises

Element	**Frequency of Occurrence** % (n=36)	**Mean ± SD** (mg/kg)	**(n)**
Cu	100	2.1 ± 0.3	(36)
Pb	100	4.1 ± 0.5	(36)
Ni	94	2.1 ± 0.3	(34)
Zn	100	3.1 ± 0.5	(36)
Cr	100	9.4 ± 0.7	(36)
V	14	1.3 ± 0.3	(5)
Ti	100	115.6 ± 16.4	(36)
Sn	14	1.4 ± 0.3	(5)
Mg	100	15,194.4 ± 580.0	(36)
Mn	100	121.1 ± 7.1	(36)
Ba	19	404.7 ± 103.6	(7)
Zr	11	45.0 ± 2.9	(4)
Ga	22	1.1 ± 0.1	(8)
Ag	97	0.1 ± 0.03	(35)
Bi	100	2.1 ± 0.0	(36)
Sr	8	543.3 ± 43.4	(3)
P	100	123,333.3 ± 1,593.6	(36)
As	14	98.0 ± 13.5	(35)
B	100	375.1 ± 59.0	(36)
Al	100	2,022.2 ± 197.2	(36)
Fe	100	889.4 ± 57.9	(36)
Ca	100	322,222.2 ± 2,222.2	(36)
Si	100	19,639.0 ± 1,884.0	(36)
Na	100	11,552.8 ± 676.9	(36)

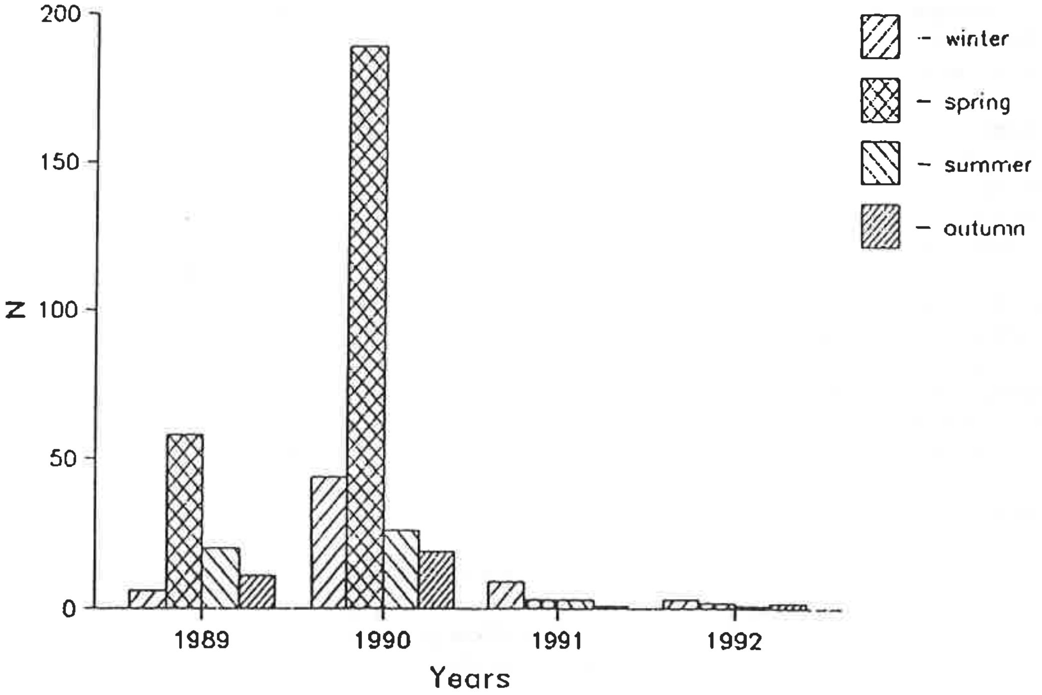

Fig. 1 Annual and seasonal variation in cetacean strandings on the Crimean coast

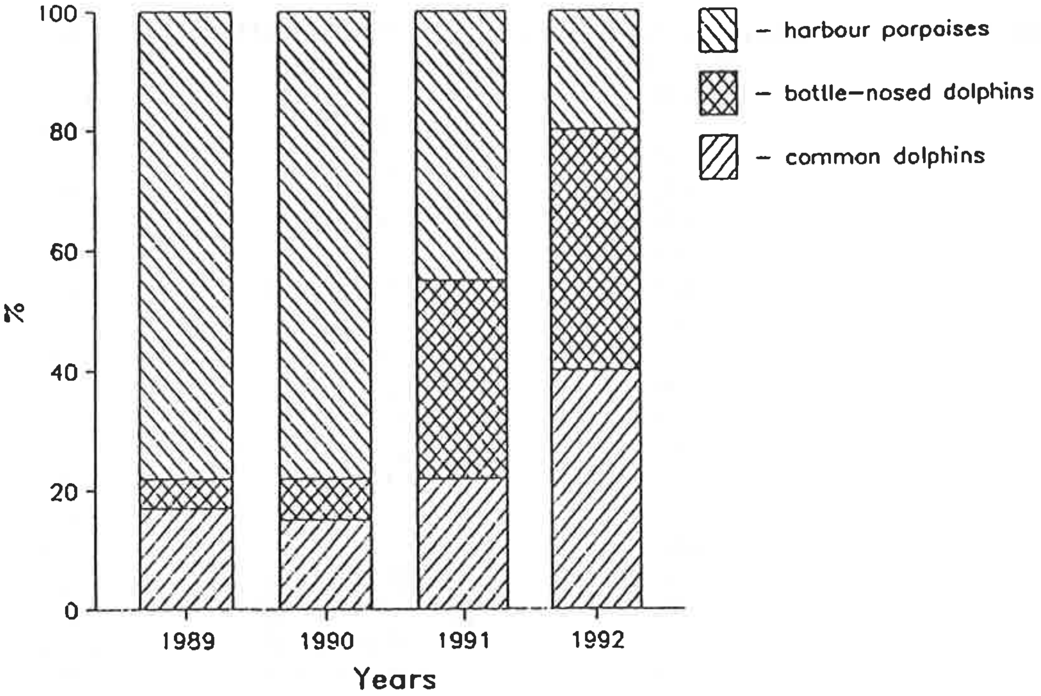

Fig. 2 Species composition of cetacean strandings on the Crimean coast

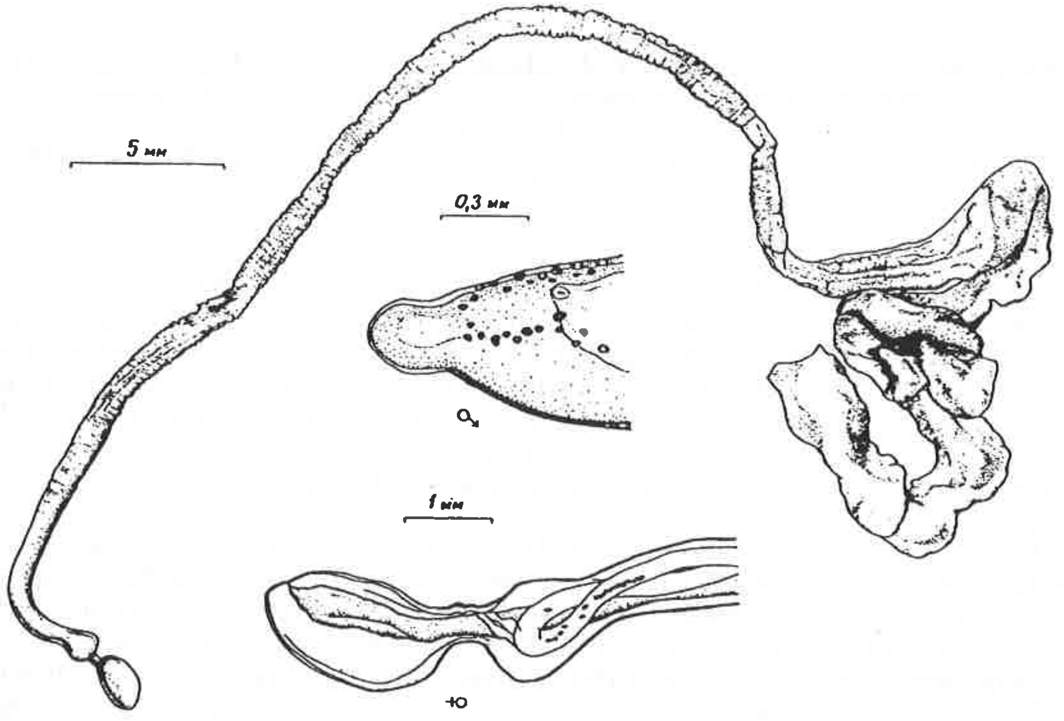

Fig. 3 *Crassicauda* sp. - the new parasite of Black Sea dolphins

COMPARATIVE MOVEMENTS OF COMMON AND GREY SEALS FROM THE INNER MORAY FIRTH, NE SCOTLAND

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The movements and foraging patterns of common (*Phoca vitulina*) and grey seals (*Halichoerus grypus*) from the Inner Moray Firth have been compared using a combination of VHF and UHF telemetry. In 1989 and 1991, a total of sixteen adult common seals were captured in the Dornoch Firth and fitted with VHF radio-tags. Activity patterns were monitored using permanent recording stations and daily locations were determined by triangulation. Five grey seals were captured in the same area in 1992 and satellite-link transmitters were fitted to obtain regular locations and activity data.

Common seals foraged within 40 km of haul-out sites on trips of up to five days. Some individual differences in favoured feeding areas were apparent but there was also considerable overlap in foraging range. Grey seals, on the other hand, travelled much more widely and there were marked individual differences in the movements of the five seals. Two seals travelled south; one to the Farne Islands and one to the Tay estuary and subsequently to the Forth estuary. Another individual travelled to Orkney and the remaining animals spent most of their time in the Moray Firth.

These data indicate that common seals have relatively restricted foraging ranges, while grey seals may travel widely and mix with animals from adjacent breeding areas.

SEASONAL VARIATIONS IN HAUL-OUT PATTERN OF GREY SEALS IN BRITTANY

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INTRODUCTION In Brittany, the presence of seals has been known for centuries by fishermen and other coastal human populations. Nonetheless, it was only in the late 1950's that naturalists reported the presence of the grey seal (*Halichoerus grypus*) around the islands of Ouessant and Molène, which lie at the western tip of Brittany. During the late 1970's and early 1980's, these seals were shown to be resident but the actual size of the group remained poorly documented as well as the yearly pup production. Indeed, only three births were officially recorded in 15 years. Consequently, the breeding status of this small population remained unclear.

In the meantime, several islands and islets of the archipelago had been protected for the biological interest of their terrestrial habitats and seabird colonies. In 1990, the UNESCO programme "Man And Biosphere" acknowledged the environmental value of the whole area by awarding it the status of MAB reserve.

In order to standardise the different status of conservation applied throughout the archipelago, and also to include marine habitats in the protected zone, it was recently suggested to develop a Marine National Park (*Parc National Marin de l'Iroise*). Prior to defining its zonal limits and providing rules for protection, many different studies are required to assess the biological interest and the role of each part of the ecosystem, as well as its tendency to disturbance from human activities in the area. The Laboratory of Marine Mammalogy in Océanopolis was therefore asked to study the resident populations of bottle-nosed dolphin (*Tursiops truncatus*), and of the grey seal, paying particular attention to the size of the populations, their breeding status, distribution and habitat utilisation, and the current level of interaction with human activities.

The purpose of this paper is to present progress to date on studies of the resident population of grey seals. The size of the population, estimates of pup production, and seasonal variation in the use of haul-out sites are presented.

METHODS The study site is a 17 km long stretch of rocks, islets and small islands oriented SE-NW and located 6 km off the mainland (Fig. 1). The main oceanographic feature of the area is the strength of the tidal current which flows north-eastwards when the tide is rising and south-westwards during ebb tide. The series of islands and rocky outcrops act as a comb through the tidal current and divides it up into numerous veins where the flow of seawater is accelerated. Only one island is still inhabited today but several others have extensive terrestrial areas that allowed farming activity in the past. Beside these islands, numerous islets (limited terrestrial area) and rocks (no terrestrial vegetation) are also potential resting sites for the seals.

Censuses have been performed every two weeks along a standardised route. Data gathered here have been collected from 29 October 1991 to 26 January 1993. Typically, these censuses took place from two hours before low tide until the turn of the tide, the period when animals were most likely to be resting at their haul-out sites. Each individual was recorded in one of the following categories: pup, 1st year, unidentified individual, adult female, adult male. Searches were made particularly for specific natural markings (scars, blind eyes, various abnormalities on the head) to help individual recognition. The noise of our out-board engine frequently induces seals that were sleeping underwater to surface close to traditional haul-out sites. Human activity in the area was also categorised (leisure motor boats, sailing boats, fishing boats steaming through the area, *Laminaria* kelp harvesting by specialised boats, *Chondrus sp*. harvesting on rocky outcrops, etc.). Data were then analysed according to four types of haul-out sites: islands, islets, large rocks and small rocks defined according to the extension of their terrestrial part.

RESULTS

Population size and breeding status Total counts on the whole area were between 25 and 49 individuals and displayed no clear seasonal trends. Since an unknown fraction of the population always remained uncensused, the total number of seals in the area must be no less than 50-60.

Pup production cannot be directly assessed by pup counts because the breeding season is poorly synchronised and birth sites are spread over many different rocks. Furthermore, adverse weather and sea conditions are frequent in November. As a direct consequence, pup counts are most likely to importantly under-estimate actual pup production. Only three pups were found with white coats in winter 1991, but, in addition, three very young and fully moulted seals were also observed swimming and interacting very closely with a female. In winter 1992, very poor weather conditions precluded censuses during the pupping season. However, in mid-December, four young seals were seen interacting with females, and two others, although isolated and not interacting, were very small and most probably born in the area. From these partial data, we infer that between five and ten pups are produced per year.

Seasonal variations in the use of haul-out sites Haul-out data have been analysed according to season (winter defined from October to March, and summer from April to September), location (Fig.1), and geomorphological type of site (Fig. 2).

At several sites, the number of resting seals is significantly differentt in winter than in summer (Fig. 1). It is particularly the case at Kervouroc islet (KERV, Fig.1) where 35% of the population can be found in winter, and an average of 12% in summer. Conversely, Serrou (SERR) and Belveignou (BELV) rocks are preferentially used in summer. Other sites do not display any seasonal differences.

Kervouroc is the remotest islet of the area and perhaps the one which provides the best combination of features (sufficient terrestrial zone, no access to boats, far from inhabited islands) for the critical periods of reproduction and moult.

When resting sites are pooled according to geomorphological type (irrespective of their precise location), significant seasonal differences in numbers of seals occur. Islands are unimportant haul-out sites in any season but islets are of prime importance in winter, with nearly 60% of the population resting on such haul-out sites. In summer, the seals have more catholic choices, also frequently resting on both high, and intertidal rocks.

The same tendency is shown by comparing the cumulative numbers of seals resting on rocks and on islets for all censuses arranged by date (Fig. 2). The result is a fluctuating pattern of attendance with islets being the predominant type of haul-out site in winter, and rocks more often used by the seals in summer.

DISCUSSION The present study provides data for the southernmost breeding locality of grey seal in Europe: its size, pup production and some details of the annual cycle of haul-out site utilisation.

It seems likely that the winter preference for islets as haul-out sites is dictated by constraints associated with the breeding and moulting seasons. Both events require that the seals stay at the same place for several weeks (two weeks for nursing the pup, nearly four for moulting).

Only places with a sufficient terrestrial zone can provide shelter against tide and adverse sea conditions, and only islets are reasonably free of human disturbance.

On the other hand, it is less clear why the animals move to smaller rocks in summer. The presence of some human activity may at least partly explain this. Summer is the harvesting season for a small intertidal red alga *Chondrus crispus,* and it is a complementary activity for many people in the area. Consequently, at this season, there is an increase in human disturbance at haul-out sites. Seals may therefore be induced to use smaller and less accessible sites during summer. Another hypothesis would be that, once the seals are free of the specific constraints of breeding and moulting, they use other resting sites that are less sheltered but perhaps closer to their feeding zones.

Compared with colonies located in the core of the grey seal European range, this population is very small. However, it now appears larger than was reported in the past. This difference is most probably due to differences in observer effort.

A notable difference with northern populations is that this resident group stays in a very restricted area (17 x 8 km) throughout the year.

Due to the small size of the population and the large number of potential resting sites, there is no concentration of animals at resting sites except during moult, for which period one islet is likely to be much more suitable than the others. During other seasons, the seals only gather in very small groups. This leads to a rather different social context and space utilisation strategy than classically reported for the grey seal. One could hypothesise that at this site, a particular bull cannot control many breeding females in the same location and therefore polygyny is limited. On the other hand, this scattered distribution allows the seals to find food in the immediate vicinity of their resting sites, which again differs from our knowledge of the species elsewhere.

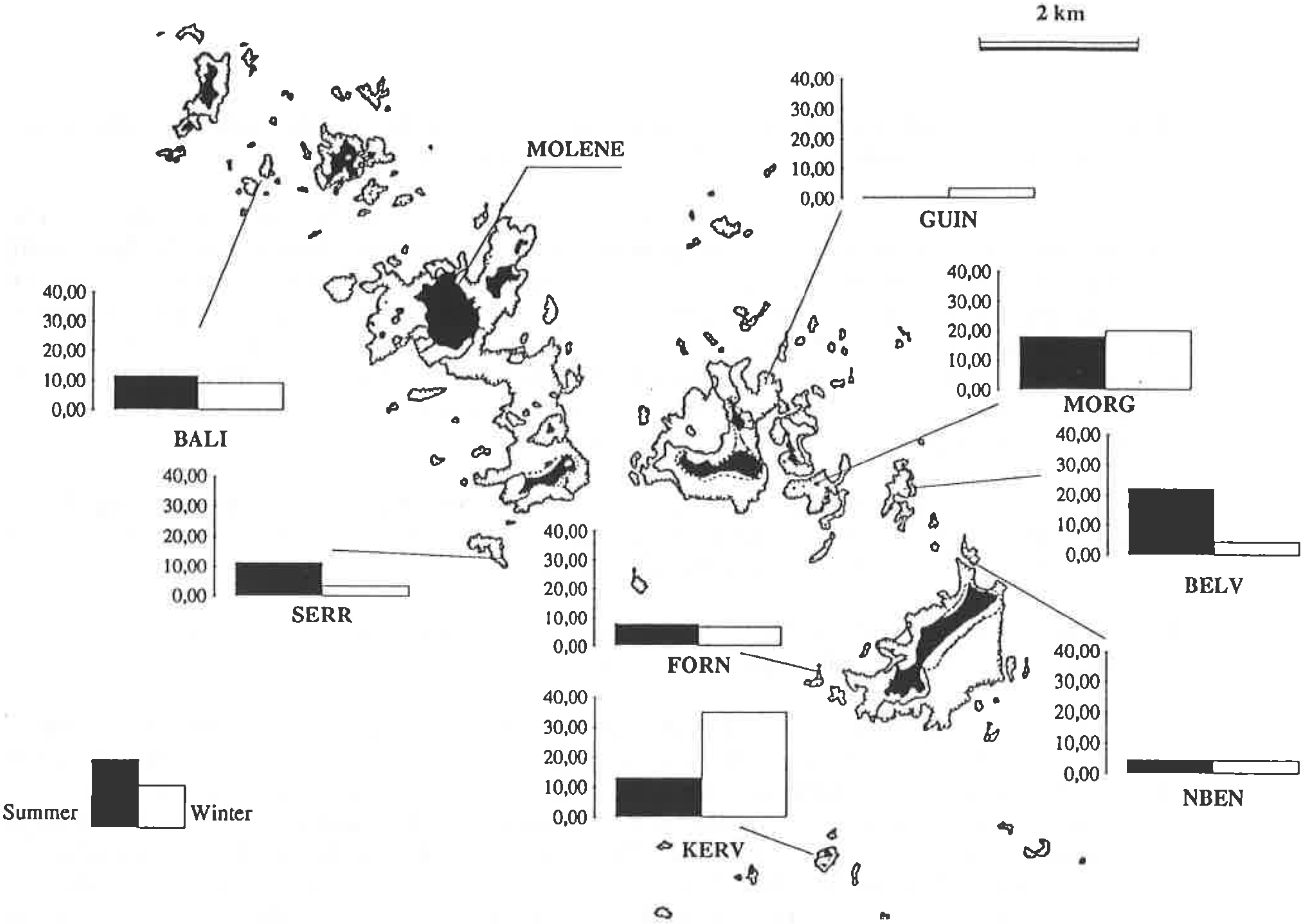

Figure 1 : Seasonal variations in geographical distribution of haul-out sites. Values indicate the percentages of seals using a given site for each season.

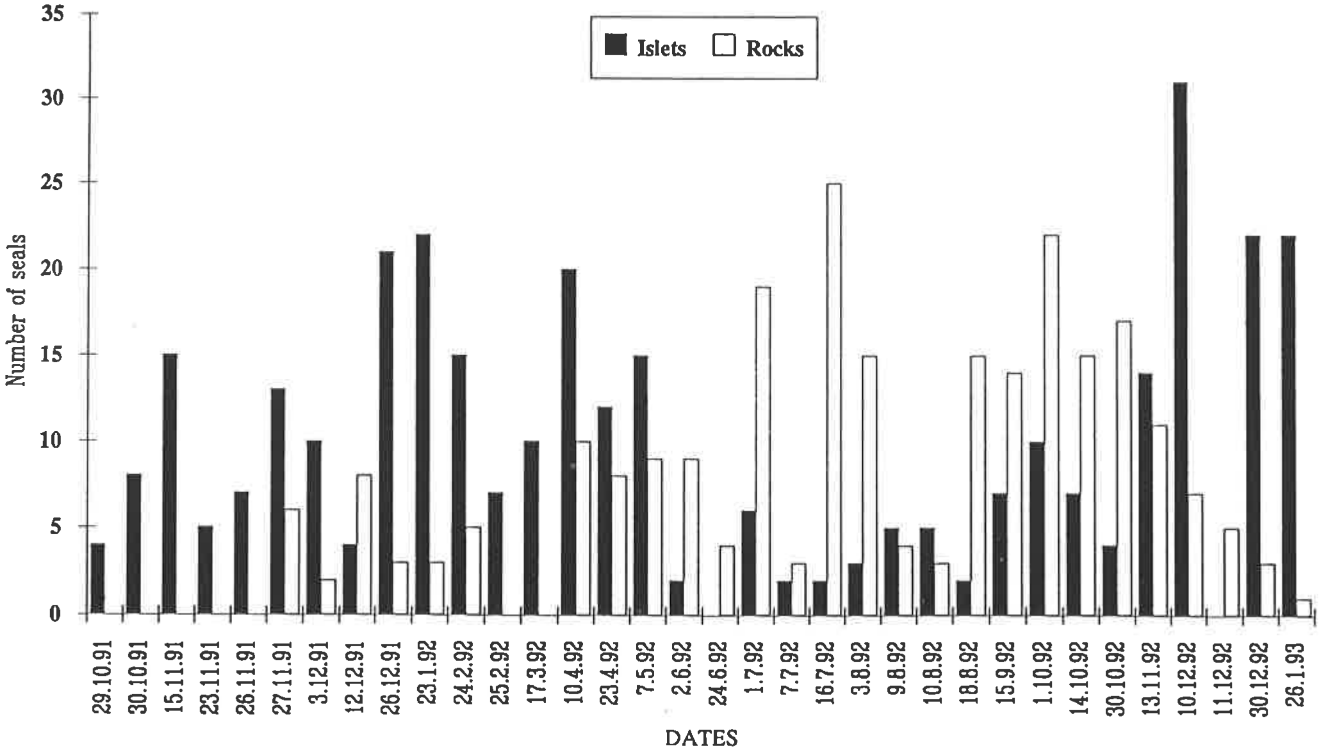

Figure 2 : Cumulated numbers of seals resting on two types of haul-out sites : islets and rocks

COLOUR MARKING OF REHABILITATED SEALS

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INTRODUCTION Seals found live stranded on the Atlantic and Western Channel coasts of France are all forwarded to Océanopolis seal clinic for treatment and rehabilitation. From winter 1988-89 until now, 60 young seals have been sent to the rescue centre. Only one of these was a harbour seal, (*Phoca vitulina*), the rest being grey seals (*Halichoerus grypus*)

Typically, these seals are recently-weaned pups (one to four months old), unable to feed efficiently enough to meet their energy requirement. When all the blubber stored during the suckling period is consumed, they get stranded ashore and are easily caught by hand. Various pathologies and injuries combine with their general weakness. An important aim of the rehabilitation strategy is to help the seals to regain their fat reserves before they are released into the sea. In the rescue centre, the health condition of the seals is very closely monitored but, by comparison, rather little is known of their fate and behavioural rehabilitation at sea once they are released. To assess the efficiency of the whole rehabilitation procedure, it is of considerable value to track released animals (Dierauf, 1990). The purpose of this colour marking programme is to provide some preliminary and unexpensive information on the dispersion and behaviour at sea of these rehabilitated seals.

METHODS The marking was designed so as to allow individual identification of animals observed from a distance at sea. Only devices glued on the top of the head are suitable for this purpose. In the present experiment, 3 x 4 cm plastic plates of different colours were used. Two plates forming an individual colour code, were glued on the fur of the head. These plates are lost when the hair is shed during moult six to ten months after release.

RESULTS Only selected examples are given here to illustrate the various dispersion and behavioural patterns shown by rehabilitated seals after release. Long-distance and short-distance movements are mapped in Figures 1 and 2 respectively.

Seal #1 This is the only harbour seal that we have had at the Océanopolis seal clinic. Found stranded in the Wash (UK), a few days after birth, it was rehabilitated at the "Kingdom of the Sea" rescue centre in Hunstanton, Norfolk, (UK), from 1 July 1991 to 13 Oct 1991. It was later observed several times in harbours and marinas of the northern coast of Brittany and in Normandy, from February to late April 1992, some 800 km southwestwards of its release site. Eventually, it became caught by local people and sent to Océanopolis on 2 May 1992. Thin, but otherwise healthy, the seal had been fed for two months and was released with its colour identification plates on 2 July 1992 at Mont Saint Michel Bay, which is the nearest locality where harbour seals are resident and breed. On 18.July 1992 it was sighted in a river near Bordeaux, France, c. 120 km inland (Fig. 1); this represents a minimum of 1,000 km swum in 16 days (minimum average distance per day of 62km). As a result of threats from fishermen, the seal was caught again and returned to Océanopolis on 29 July 1992. Released in the bay of Brest on 2 August 1992, the animal spent four weeks moulting in a nearby estuary. It was sighted for the last time on 15 September 1992 seaward of here (Fig. 2); moult had been fully completed and colour plates were lost.

Seal # 2 This grey seal had been treated and rehabilitated in La Rochelle Oceanographic Museum, France, and was released on 19.Dec 1989 at "*les Sept Îles*" archipelago off the north coast of Brittany where grey seals are resident and breed. After five days of violent south-west gales, it was found live stranded in Etel, on the south coast of Brittany, 350 km from its release site (Fig. 1). The minimum average distance swum per day was 70 km.

Seal # 3 Stranded on 10 Jan 1990 in Southeast Brittany, this grey seal was rehabilitated at Océanopolis seal clinic and released on 12 Feb 1990 in the bay of Brest, an area where wild grey seals are occasionally seen foraging but are not truly resident. It was caught in a trawl in the south-west of *Île d'Yeu* on 22 Feb 1990 and immediately released by the crew (Fig. 1). This represents at least a 300 km trip performed in ten days.

Seal # 4 This grey seal is the only case of an animal treated in our rescue centre, released in the bay of Brest, that has been observed in a local group of resident grey seals.

Found stranded on 5 Jan 1992, this seal was released after treatment on 26.March 1992 in the bay of Brest. It was observed less than three weeks later during routine census operation in the region of *Archipel Molène* within a group of grey seals resting at a haul-out site (Fig. 2). Later, it was re-sighted at various places in the area. Eventually, it settled in mid-July at another haul-out site in the north-west of the area where we sighted it, during each monthly census operation until December. At that time it had completed its moult and consequently lost its colour identification plates. This animal displayed the same routine activity as the other members of the group in which it had settled.

Other seals (movements not mapped on the figures) Besides these selected examples, numerous seals released in the bay of Brest have been repeatedly observed within the limits of the bay for periods lasting from several weeks to five months. Most often, these animals were very precisely located and displayed routine activities between well-defined haul-out sites and foraging zones. They were seen hunting successfully in estuaries and in tidal currents, and resting on some inaccessible rocks. They all disappeared from the area by late summer and we had no sighting of them from the exterior of the bay.

DISCUSSION It is not possible to draw firm conclusions from the present results about an optimal rehabilitation strategy since the data set is still limited. However, these examples illustrate various dispersion patterns and various degrees of behavioural rehabilitation at sea. Typically, seals released after treatment can display two types of dispersion: immediate long-distance wanderings as opposed to at least temporary settling in a restricted area.

Seals # 1 to 3 have swum hundreds of kilometres in the first week after release; they illustrate the first type of dispersion. This pattern would appear as an indication that survival in the wild may be unlikely since performing such long-distance movements is scarcely compatible with the exploration of a given environment, the discovery of its food sources and resting sites, and of the temporal variations of these two basic resources (mainly governed by tidal and activity rhythms). Accordingly, these seals became stranded again or were caught by man rather rapidly after they had performed these long distance trips. The exploration of the surrounding environment and development of behavioural routines adapted to the local resources require that, after the initial period immediately following release into the sea, the animal stays in a given area for a substantial amount of time.

Seal # 4 and other individuals recorded in the bay for several weeks or months after their release date, stayed either within less than ten kilometres or within a few tens of kilometres for very extensive periods; they illustrate the second dispersion pattern. These animals showed a successful development of activity routines since they were observed repeatedly using the same resting sites and foraging zones for long periods. Seal # 4 showed the highest degree of rehabilitation ever recorded for our rescue centre since it joined a resident group of grey seals and apparently followed their activity rhythm. Although the other seals were not observed in a resident group, we also consider them as successful. Indeed, within the limits of the bay of Brest, they acquired the basic behaviour necessary to allow them an independent existence. They then left this sheltered area and moved to the open sea where they were no longer sighted. However, due to their successful behavioural rehabilitation at sea, they probably did this in much more favourable conditions than the seals which wandered long distances immediately after release.

REFERENCE

Dierauf, L.A. (Editor). 1990. *Handbook of marine mammal medicine: health, disease and rehabilitation.* CRC Press, Boca Raton. 735 pp.

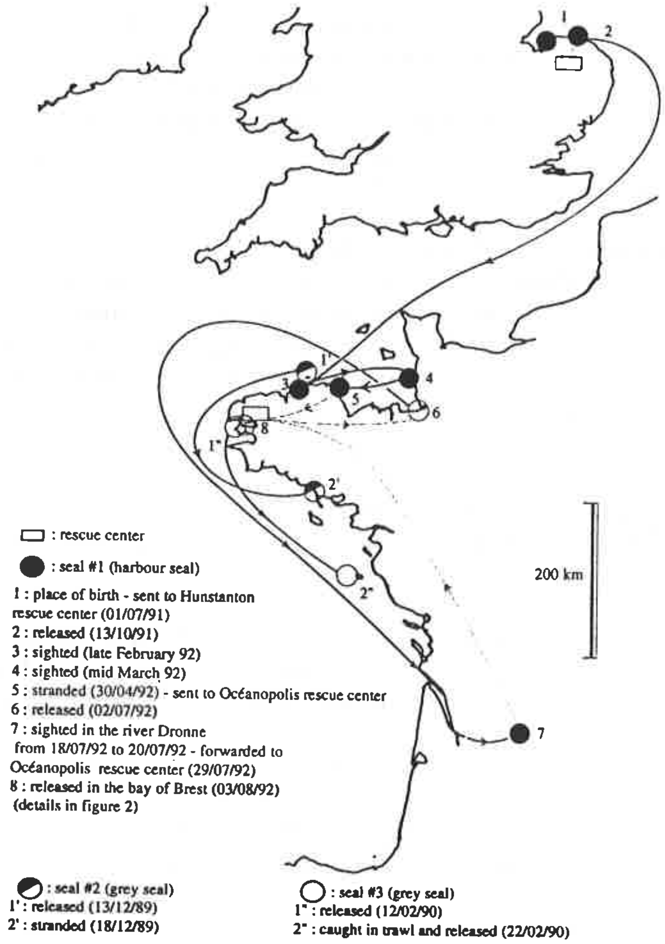

Fig. 1 Long-distance movements of three seals along the Atlantic coast and in the English Channel

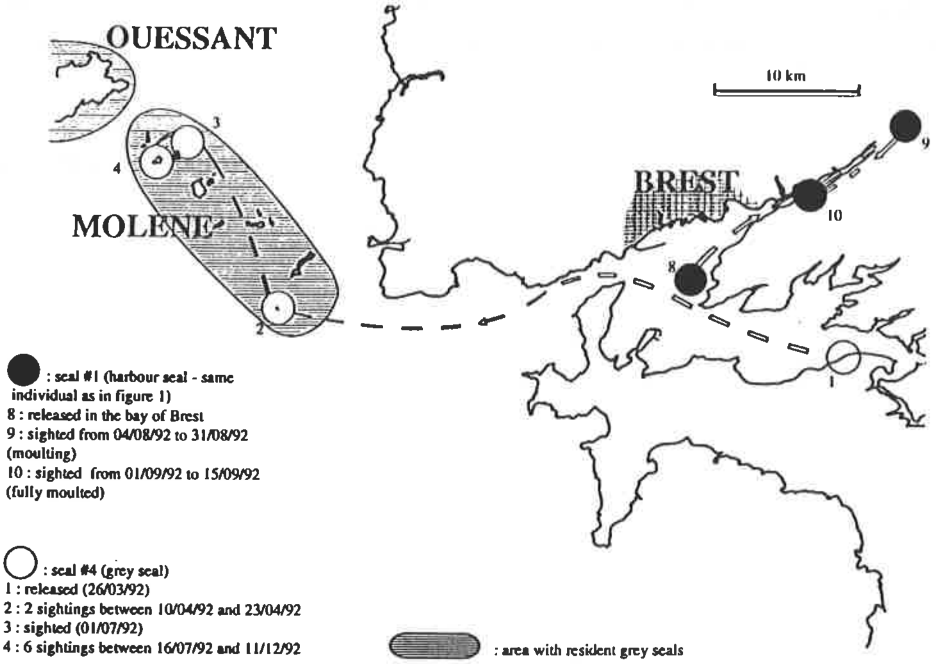

Fig. 2 Short-distance movements of two seals released in the bay of Brest, France

SIXTH ANNUAL REPORT OF THE EUROPEAN CETACEAN SOCIETY: 1992

Membership of the European Cetacean Society at the start of the Inverness Conference, totalled 351 from 28 countries (21 European), with Italy (98), Germany (58), UK (57), Spain (24), the Netherlands (23), and Denmark (22) having the highest representation. Other member countries include Belgium, Czechoslovakia, Faroes, Finland, France, Iceland, Ireland, Norway, Poland, Portugal, Romania, Russia, Slovenia, Sweden, Switzerland, and Australia, Canada, Ecuador, Japan, Peru, USA and Vanuatu.

A very successful conference was held in San Remo, Italy between 20 - 22 February, on the theme *Marine Mammals and Fisheries*. Five invited speakers attended: Bill Perrin and Bob Brownell from the United States, John Hislop from Scotland, Antonio di Natale from Italy, and Alexey Birkun from the Ukraine. Drasko and Alan Serman from Croatia were invited to speak but were unable to attend for reasons beyond their control. The abstracts of that meeting were published as proceedings under the title *European Research on Cetaceans - 6.*

Following information presented at that meeting about the serious conservation status of cetaceans in the Black Sea, a statement of concern was prepared by the Council of the ECS, in conjunction with Dr Alexey Birkun, for sending to the relevant authorities of the countries bordering the region.

On a more positive note, the European Commission, through the London based organisation Logica, selected the society as one of ten special interest groups out of four hundred, with a view to developing the use of electronic communication (E-mail) within the membership.

Three newsletters were produced during the year, reviewing recent research and news items in Europe and elsewhere in the world, conservation issues, cetacean meetings and publications, and with requests for biological material. We are very grateful to Marjan Addink and Joke Bakker for their dedication in helping with the editing of the newsletter.

In order to facilitate closer cooperation between the ECS and the European Association for Aquatic Mammals (EAAM), an exchange of delegates at annual meetings was initiated, with exchange of information about the respective societies in eachothers' newsletters. Christina Lockyer represented the ECS at the 1992 annual meeting of the EAAM

Finally, the European Cetacean Society has continued to provide advice to government departments and non-governmental organisations in various countries, and specialist information for various public enquiries.

PETER EVANS
(ACTING SECRETARY)

FINANCIAL REPORT FOR THE YEAR UP TO 16 FEB 1993

CREDIT

Balance as of 19 Feb 92	£5,205.10

Credit	£
Membership & donations	2,686.11
Conference fees from San Remo	1,212.07
Sale of Proceedings	210.20
Transfer of Funds from Tethys	4,581.68
Conference Fees for Inverness	125.00
Interest	189.79
Total Income	£9,004.85

Debit	£
Secretarial expenses at SMRU	477.50
Council members' expenses	494.86
Publications (Proc., Newsletters)	4,768.50
Postage, envelopes, etc	1,170.00
Conference costs	519.52
Total Expenditure	£7,430.38

Balance as of 16 February 1993	£6,779.57

PHILIP HAMMOND
(TREASURER)

EUROPEAN CETACEAN SOCIETY

The **European Cetacean Society** was formed in January 1987 at a meeting of eighty cetologists from ten European countries. A need was felt for a society that brought together people from European countries studying cetaceans in the wild, allowing collaborative projects with international funding.

AIMS (1) to promote and co-ordinate the scientific study and conservation of cetaceans;
(2) to gather and disseminate information to members of the society and the general public.

ACTIVITIES The Society set up seven international working groups concerned with the following subject areas: sightings schemes; strandings schemes; cetacean pathology; bycatches of cetaceans in fishing gear; computer data bases that are compatible between countries; the harbour porpoise (a species in apparent decline in Europe, and at present causing serious concern); and a regional agreement for the protection of small cetaceans in Europe (in co-operation with the United Nations Environment Program/Convention on the Conservation of Migratory Species of Wild Animals, Secretariat in Bonn, Germany). Recently, some of these have been disbanded, having served their purpose, and two new groups (covering the North & Baltic Seas and the Mediterranean Sea respectively) have been set up. The names & addresses of contact persons for all working groups are given at the end.

Contact persons have been set up in each European member country, where appropriate, to facilitate the dissemination of ECS material to members, if necessary carrying out translations into the language of that country. Their names & addresses are also given below.

A newsletter is produced three times a year for members, reporting current research in Europe, recent publications and abstracts, reports of working groups, conservation issues, legislation & regional agreements, local news, and cetacean news from other parts of the world.

There is an annual conference with talks and posters, and at which the annual general meeting is held. The results are published as annual proceedings, under the title *European Research on Cetaceans*. Besides the present volume, six others have been published for conferences held in Hirtshals (Denmark) in 1987, Tróia (Portugal) in 1988, La Rochelle (France) in 1989, Palma de Mallorca (Spain) in 1990, Sandefjord (Norway) in 1991; San Remo (Italy) in 1992. At intervals, workshops are also held on particular topics, and the results published as special issues of the newsletter. A workshop on the harbour porpoise, held in Cambridge (England) in 1988, was published as newsletter no. 6; a sightings workshop held in Palma de Mallorca (Spain) in 1990 is published as newsletter no. 10; and a workshop to standardise techniques used in pathology of cetaceans held in Leiden (Netherlands) in 1991 is published as newsletter no. 17.

Membership is open to *anyone* with an interest in cetaceans. The annual subscription is **£25** for full and institutional members, or **£15** for those who are 25 years of age or younger, full-time students or unwaged. Payment may be made at the Annual Conference in pounds sterling or the currency of the host country. During the year, payment may be made by cheque drawn on a UK bank, or Eurocheque or by direct transfer in pounds sterling in the name of the *European Cetacean Society* into bank account no. 7801067 (bank sort code 30-91-56) of Lloyds Bank, 3 Sidney Street, Cambridge CB2 3HQ., UK. Payment in excess of the membership fee will be gratefully received as a donation to the Society. Please send subscriptions to the Treasurer, **Dr. P. Hammond, SMRU, c/o British Antarctic Survey, High Cross, Madingley Road, Cambridge CB3 0ET, UK.**

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