

# **Identification of Morgan's discrete stereotyped call repertoire and matching to sounds recorded from wild North Atlantic killer whales**

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## **Executive summary**

This study aimed to use the acoustic repertoire of stranded killer whale “Morgan”, rehabilitated by the Harderwijk Dolfinarium, to attempt to identify the wild population and possibly natal group to which Morgan belongs. Acoustic recordings were made at Harderwijk, during which 12,828 high quality pulsed calls were produced by Morgan. We used a subset of 10% of these calls to classify Morgan's acoustic repertoire using standard methods of killer whale call classification, and then compared calls in Morgan's repertoire to previously identified call types of North Atlantic killer whales. The comparison was made to all known published catalogues, non-published catalogues provided by other researchers, and analyses of our own acoustic recordings. The cumulative discovery curve of call types in Morgan's repertoire leveled off quite strongly after 800 calls analysed, with 9 stereotyped call types that initially could be divided into 21 total subtypes. Variable calls made up 7% of the calls analysed, similar to published proportions in free-ranging killer whales. Thus, we feel that we have been able to make a good initial description of Morgan's repertoire, though analysis of more of the sounds would be useful. We found good ‘likely’ matches to 3 of the 9 stereotyped calls in Morgan's repertoire with calls recorded from Norwegian pod NP, one possible match was to Norwegian pod NA, and another possible match to an unknown pod of herring-feeding killer whales. Our results strongly indicate that Morgan is from the Norwegian herring-feeding population of killer whales. However, many of Morgan's calls, including the most commonly produced call type, did not match any calls in our catalog ascribed to pod NP. Pod NP is also reported to produce sounds which were not identified in Morgan's repertoire. Thus, we cannot conclude that pod NP is Morgan's natal pod, but we do consider it likely that Morgan is from a group closely related to pod NP. Identification of Morgan's natal pod using acoustic sharing is made difficult by our limited knowledge of group-specific calling patterns in Norwegian killer whales, and how call repertoires might vary over time.

## Methods

Acoustic recordings were collected using a High Tech Instruments HTI-96-MIN hydrophone with pre-amplifier (flat frequency response: 0.002-30 kHz). The hydrophone was connected to an Edirol UA-25 soundcard and continuously recording onto a laptop using PAMGUARD (Gillespie et al., 2008) at a sampling rate of 96 kHz. The hydrophone was placed behind a protective net in a channel connecting the pool where Morgan is held and the pool where bottlenose dolphins are held. The channel was closed so the animals could not see each other. Some sounds from bottlenose dolphins were audible in the recordings, but they were easily separated from Morgan's sounds based on amplitude of the sounds and known species differences in sound production. Any sounds not clearly ascribable to Morgan were excluded from analysis.

Acoustic recordings were inspected to identify pulsed signals produced by Morgan using Adobe Audition 2.0© (Blackmann-Harris window; FFT=2048; 100% window width). Although whistles and clicks were also ascribed to Morgan, only pulsed calls were marked and analysed further. The signal to noise ratio (SNR) quality of each pulsed call was scored on a scale of 1 to 3 (1 being poor quality and 3 being high quality). Only pulsed calls of high quality SNR (quality 3) were used further for classification.

Classification of calls into types was initially conducted by visual assessment of the spectrograms of a subset of the high quality pulsed calls. Spectrograms were limited to a frequency range up to 16 kHz and were produced using the following parameters: FFT size=2048; overlap: 87.5%; window function: Hann; frequency resolution: 47 Hz; time resolution: 18.7 ms. All spectrograms presented in this report were also produced with these parameter settings.

Repetitive pulsed calls (occurring at least twice) that fell into distinct structural categories, based on their time-frequency contour, were assigned to a discrete call category (as in Ford, 1987). Two observers (FS and AD) classified the sounds and if a question arose as to the assignment of a call to a category, aural assessment was used and a third observer (PM) was consulted. FS and PM can be considered experienced observers of killer whale calls, while AD was a relatively untrained observer. If a discrete call was only seen once in our sample it was initially assigned to the variable call category. Discrete calls were classified alphanumerically, using M for Morgan followed by a number, which was assigned arbitrarily in the order that calls were

classified. If subtypes were identified a roman small type numbering followed, so that for example subtypes of call M1 would become M1i, M1ii, M1iii, etc.

Once all calls were classified, a cumulative discovery curve of the call subtypes resulting from the classification was plotted to investigate whether a plateau was reached. The level of flattening (plateau) in the discovery curve is a useful indicator of how completely we have been able to describe Morgan's discrete call repertoire.

We then compared Morgan's call types (with all subtypes) to known discrete calls recorded from wild killer whales of the North Atlantic. This included killer whales recorded off Norway, Iceland and Shetland. Comparisons were conducted with all catalogues we had available from these three locations. A call catalogue of killer whales from Shetland was kindly provided by Dr. Volker Deecke. Comparisons with Icelandic calls were conducted using the call catalogue included in Moore et al. (1988) and from our preliminary classification of a sample of recordings we collected over three field seasons (2008-2010) off Vestmannaeyjar, in southern Iceland. Most acoustic data available was from Norway, which included the catalogues Moore et al. (1988), Strager (1993), Van Parijs et al. (2004), van Opzeeland et al. (2005) and Shapiro (2008). We further made comparisons to a Norwegian call catalogue developed and kindly provided by Heike Vester. Finally we also compared Morgan's repertoire to a catalogue developed by Floriane Plard of recordings our research group has collected in Norway between 2005 and 2009.

## **Results and discussion**

We collected a total of 124 hours of recordings between 18 and 23 October 2010. From these recordings we identified a total of 18,351 pulsed calls produced by Morgan, of which 12,828 were of high quality signal-to-noise ratio. Of these we have classified a subsample of 1302 calls (~10%), which contained sounds recorded on four different days and at different times of the day (both day and night time) to try to capture as much variability in Morgan's sound production as possible.

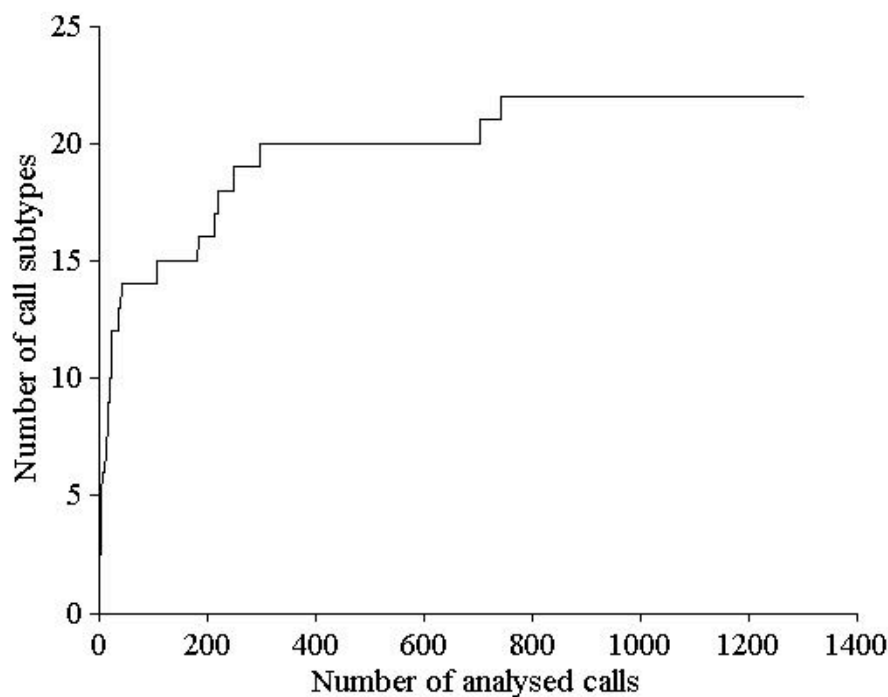
### *Characterization of Morgan's repertoire*

The classification resulted in 9 discrete call types (Appendix 1), which we have initially sorted into 21 total subtypes. The most common call types were M2 and M6 (Table 1). Variable calls made up 7% of the calls analysed.

**Table 1.** Percentage of occurrence of different call types, total number of calls for each type given in parentheses.

Call type	% of total calls
M1	5% (70)
M2	22% (290)
M3	1% (18)
M4	2% (20)
M5	1% (11)
M6	58% (759)
M7	3% (36)
M8	0.1% (2)
M9	0.2% (3)
variable	7% (93)

The cumulative discovery curve (Figure 1) shows how many call subtypes were identified against the cumulative number of analysed calls. Most call types and subtypes were identified after the analysis of 300 calls but it took more than 700 calls for all types to be identified. This suggests that Morgan might be producing sound types at different times and so our selected sample could still be missing a few of Morgan's types. Nevertheless, the cumulative curve leveled at 22 subtypes despite the analysis of a further ~500 calls, therefore we have likely identified most of Morgan's acoustic repertoire.

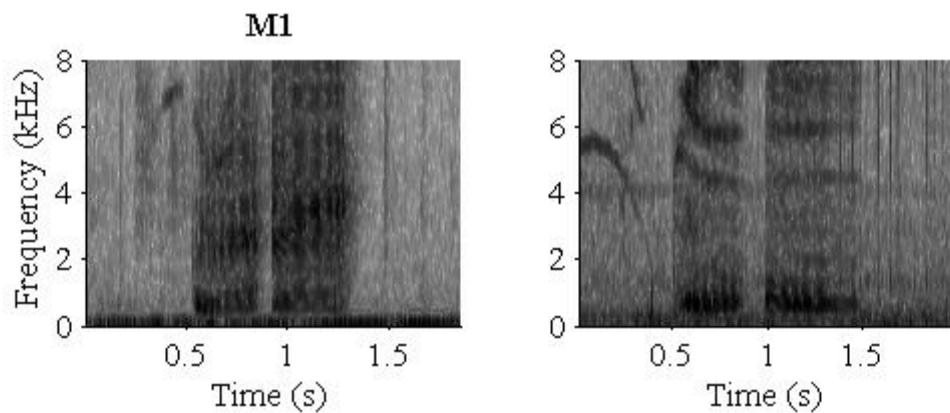


**Figure 1.** Cumulative discovery curve of all call subtypes. Variable calls were included as one subtype.

### *Matching Morgan's repertoire to North Atlantic call catalogues*

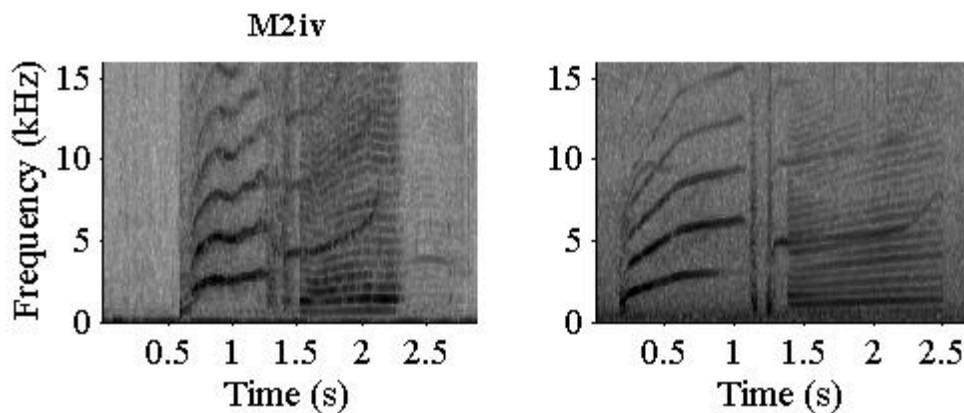
We found potential acoustic matches to five of the 9 call types produced by Morgan. Matches were only found to Norwegian killer whales sounds, and none to either Icelandic or Shetland killer whale sounds. Three of the matches were considered to be very similar matches, hereafter termed 'likely' matches. Two other calls matched, but not perfectly, calls in the catalogue, and are hereafter termed 'possible' matches.

Call type M1 was considered a likely match to a call found in two Dtag recordings: Dtag oo05\_321s deployed in the Tysfjord area in November 2005 and Dtag oo09\_144a deployed off Vesterålen in May 2009 (Figure 2). Both tags were deployed on individuals belonging to pod NP of the Norwegian population.



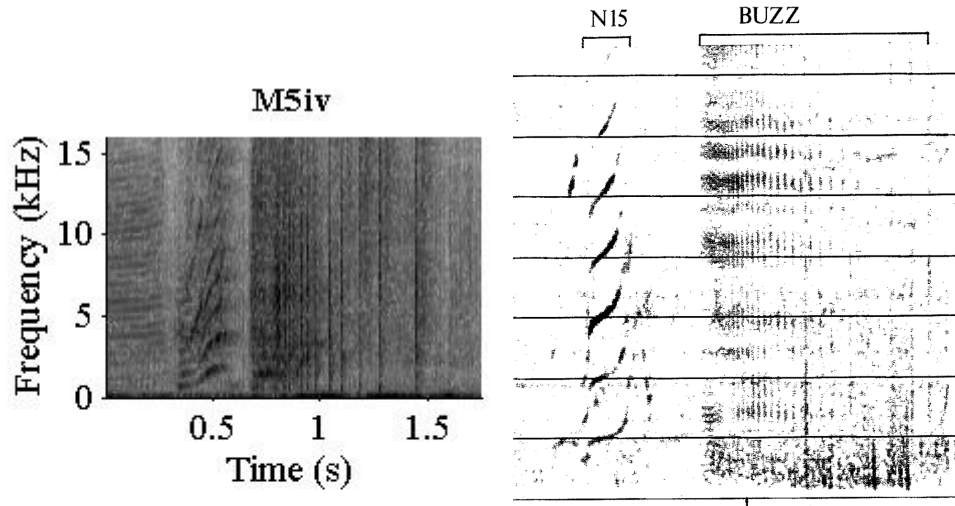
**Figure 2.** Likely match of Morgan's call M1 to a call recorded in 2005 from Norwegian NP pod.

Call type M2 (subtype iv) was considered a likely match to a call also recorded on Dtag oo09\_144a (Figure 3).



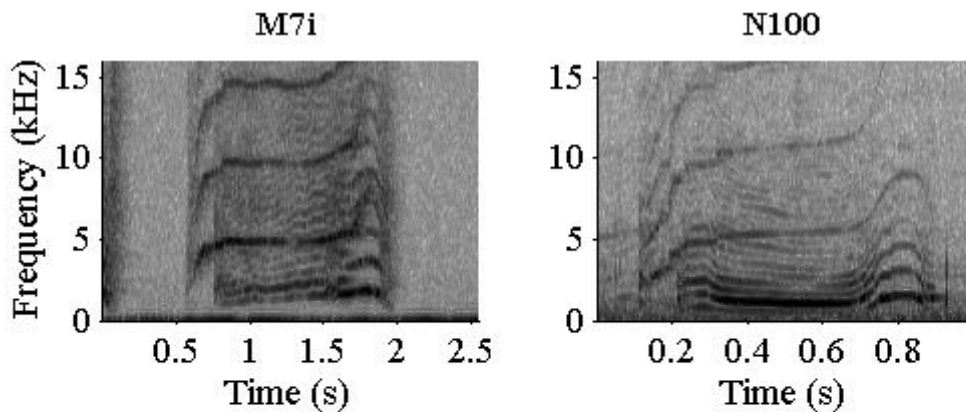
**Figure 3.** Likely match of Morgan's call M2iv to a call recorded in 2009 from Norwegian NP pod.

Call type M5 (subtype iv) was considered a likely match to the compound call N15+buzz described in Strager (1993) (Figure 4). This call was reported to have been produced by pods NP, NT and NK.



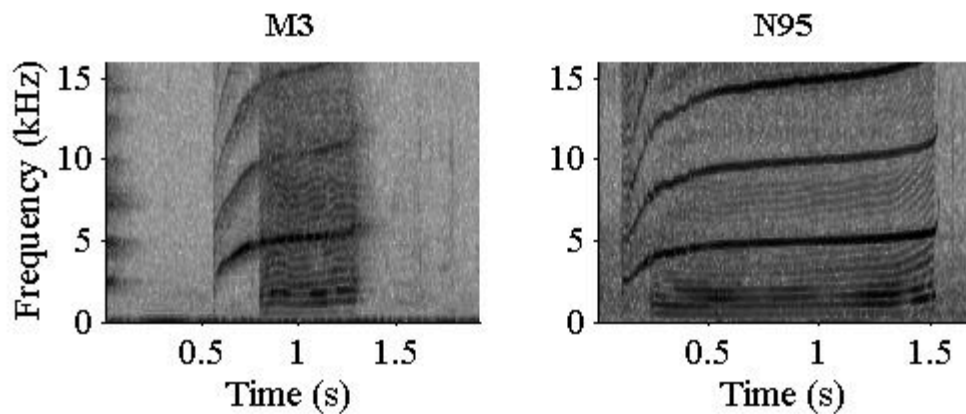
**Figure 4.** Likely match of Morgan's call M5iv to a call reported in Strager(1993) catalogue. The spectrogram is reproduced from Strager (1993), each horizontal line is 1 kHz.

Call type M7 (subtype i) was considered a possible match to call N100 described in Shapiro (2008), which was recorded in tag oo06\_327s deployed in an unidentified group of carousel feeding killer whales (Figure 5).



**Figure 5.** Likely match of Morgan's call M7i to a call described in Shapiro (2008).

Call type M3 was considered a possible match to call N95 described in Shapiro (2008), which was recorded in tag 314s deployed in group NA (Figure 6). It was also recorded in Dtags deployed in groups NA and NG.



**Figure 6.** Likely match of Morgan's call M3 to a call reported in Shapiro (2008).

These results suggest that Morgan could be from pod NP, given that three of Morgan's call types were matched to calls produced by pod NP. NP pod was regularly seen in Vestfjord and Tysfjord in the winter months at least up to 2005. Members of that pod were then sighted by our research group off Vesterålen in May 2009. No killer whales were sighted during field work conducted by our research group in May 2010 in northern Norway, however poor weather conditions prevented a survey of offshore areas.

However, not all of the calls ascribed to pod NP were found to be produced by Morgan, and some of Morgan's calls were not matched to pod NP. For example, a match was not found to call M6, the most commonly produced by Morgan. Given that pod NP's repertoire was described in detail in Strager (1993), more matches might have been expected if Morgan did indeed originate from this pod. However, it is also possible that pod NP's repertoire has changed somewhat since the report by Strager (1993).

## Conclusions

Our results strongly indicate that Morgan originates from the herring-feeding population of killer whales in Norway. While most matches of call types were to pod NP, we cannot conclude pod NP is Morgan's natal group because only a portion of her repertoire matched calls from pod NP. It is plausible that Morgan could originate from a less known related pod that has a similar acoustic repertoire to that of NP pod, but for which a full repertoire description is not yet available.

We stress that the results presented here should be considered preliminary. Further analysis of sounds produced by Morgan could lead to identification of more stereotyped

calls in her repertoire. The catalogues of sounds from the North Atlantic were of highly variable quality and age, so updated complete catalogues of North Atlantic killer whale calls would be helpful. Finally, acoustic surveys of killer whales in the North Atlantic have not entirely covered all North Atlantic populations, and surveys even within the better-studied Norwegian population are also likely to be incomplete. Thus, more fieldwork aimed at recording sounds from identified groups of killer whales in the North Atlantic could help to identify Morgan's natal pod.

## Acknowledgments

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## Appendix 1: Morgan discrete call repertoire

