PELAGIC DELPHINIDS OF THE MEDITERRANEAN SEA HAVE DIFFERENT WHISTLES

Alexandre Gannier (1), Sandra Fuchs (1)(2), Julie N. Oswald (3)

(1) Groupe de Recherche sur les Cétacés (GREC), BP715, 06633 Antibes, France.
(2) Centre d'Océanologie de Marseille, Campus de Luminy, 13288 Marseille, France.
(3) Hawaii Institute of Marine Biology University of Hawaii, 46-007 Lilipuna Road, Kaneohe, Hawaii 96744, USA.

Introduction

The western Mediterranean basin shelters five common delphinid species among which four are inhabiting slope and offshore waters (Gannier, 2005): the long-finned pilot whale (*Globicephala melas*), Risso’s dolphin (*Grampus griseus),* striped dolphin (*Stenella coeruleoalba*) and short-beaked common dolphin (*Delphinus delphis*). Whistles are commonly emitted by the three latter species, and pilot whale vocalizations routinely include pulsed calls. In the eastern tropical Pacific, Oswald et al. (2003, 2007) found that striped dolphin whistles were difficult to discrimimate from those of eight other delphinids, in particular common dolphins. These authors did not include Risso’s dolphin in their studies because data were too limited. Their classification method involved extraction of 12 variables from whistle spectrographic contours. Wide ranging small boat surveys of GREC in the Mediterranean Sea included towed hydrophone sampling, with systematic recording of good quality cetacean vocalizations. The aim of this study was to discriminate whistles of Mediterranean Risso’s, striped and common dolphins, taken from GREC sound archives (1994-2007). We develop new software (Seafox) to extract 15 variables and processed our data using statistical testing and a multi-variate discrimant analysis.

Material and Methods

The primary data set comprised 120 whistles of common dolphins, 158 of Risso’s dolphins (western basin) and 277 samples of striped dolphin (northwestern basin) (Figure 1). Whistles of common dolphins came from six sightings made from 1994 to 2006 in the western basin including Alboran Sea and Sicily surroundings. Those of Risso’s dolphins came from six sightings obtained between 1999 and 2007 in the whole western basin. The striped dolphin signals were taken from 18 sightings made between 1999 and 2006 in the northwestern basin (north of 41°N). The primary data set was used to design a discriminant model from the most significant combination of extracted variables. A striped dolphin test data set consisted in 263 whistles from the southwestern basin (south of 40°N): the same variables were extracted and entered to test the discriminant model.

Although the hydrophone response is flat (+/- 3 dB) up to 32 kHz, only the 0.2-22 kHz bandwidth was collected either with a Sony TCD-8 DAT or a Marantz PMD-670 (digital compact flash storage). DAT format were converted to *.wav file by digital-analog conversion and re-digitized by the PC sound card. All delphinid recordings were played and stored in files of about 90 seconds, the content of which being individually described and coded in an Access database. Data-base requests were performed to select relevant recordings from this 4000+ sample set, and the whistles were individually extracted from the selected 90 second recordings and stored for subsequent contour extraction.

Seafox extraction program was written in Matlab 6.0 and based on 512 point Fast Fourrier Transforms of whistles sampled at 44.1 kHz, using a Hanning window with 25% overlap. Peak frequencies were extracted from every window and stored for contour plotting. Synthetic spectrogram contours could be improved by several program options: high/low filtering, selective amplification, click removing, smoothing, and automatic or manual interpolation.

Fifteen variables were extracted from each contour: the duration, frequency range, number of frequency extrema, beginning, ending, maximal and minimal frequencies, minimal, maximal initial and final frequency slopes (computed on three or seven points), presence of harmonics.

Statistical study started with a pair-wise comparison of each variable for the three species (Mann-Whitney test). A Principal Component Analysis (PCA) was then performed for each species to express the variance of the whistle repertoire. PCA was repeated for all species together to evidence species discrimination. Finally, a discriminant function was researched to optimize the classification of the three species whistles. This discriminant function was then used as a model to classify individually every sample, i.e. to test the efficiency of the whole process. As a last stage, we introduced the additionnal SW striped dolphin sample set to check the robustness of our model with an independent data set.

Results

Seafox software enabled processing of the contours of most whistles - only 10-12% of the initial selection were rejected during the contour extraction process. Among the 15 extracted variables, four were significantly different among the three species: the duration, harmonic presence, maximal frequency and frequency range. For example, average duration was shorter for common dolphins (0.47s) than for Risso’s dolphin (0.65s) or striped dolphins (0.73s), and the latter had more whistles containing harmonics than the two other dolphins. The frequency range of striped dolphin repertoire was wider (7,296Hz) than for Risso's (6,365Hz) and common dolphin (4,622Hz). Accordingly, striped dolphin average max frequency was higher (15,163Hz) than for other species (resp, 14,652 and 13,149Hz).

Other variables were useful to discriminate one species from the two other: initial and final slopes were significantly different between common and the other dolphins, as was the number of extrema. Initial and minimal frequencies were significantly different for striped dolphins compared to the other dolphins. (Table 1)

On the contrary, three variables were not different among species, such as the final and average frequencies or the maximal positive slope.

PCA indicated that four factorial axes explained 72% of the total variance for striped dolphin whistles, 75% for those of Risso's dolphin and 70% for those of common dolphins. PCA for the three species together indicated that three components explained 22%, 19% and 18% of the variance - maximal and ending frequencies, and frequency range were important for the first principal component, and final and max slopes for the second component. Duration and minimal frequencies were strongly represented in the third component, and the initial slope was a strong contribution in the fourth component which accounted for 10% of the variance. Common dolphin whistles were well identified on two factorial plans of the three species PCA (Figure 2), which also showed that Risso's and striped dolphins were intermingled.

The discriminant analysis was carried out with 12 variables and showed the best classification could be obtained with a combination of two discriminant axis, the first one (80% of variance) with frequency range, beginning and min frequencies, and the presence of harmonics, and the second including also the beginning and ending slopes.

Globally, the discriminant model attributed 62,9 % of the whistles to the correct species, however the percentage of correct classification was high for the common dolphin (70,8%) and the striped dolphin (76.5%) and low for the Risso's dolphin (32.9%) (Table 2). Almost 45% of Risso's dolphin whistles were attributed to striped dolphins. Chi-2 testing showed that correct classification was significantly better than chance for striped and common dolphins.

When we tested the additional striped dolphin data set (SW basin, n=263) with the discriminant model, 76.4% were correctly attributed to their species and the rest were wrongly classified either as Risso's dolphins (12.5%) or as common dolphins (11%). The percentage of correct classification was identical for the « test » striped dolphin whistles as for the initial data set, hence showing the robustness of the model.

Discussion

Classification efficiency

ROCCA(Real-time Odontocete Call Classification Algorithm), a contour analysis software previously developed for delphinids in the Eastern Tropical Pacific (Oswald et al., 2003; 2007), performed equally well to differentiate the Mediterranean common and striped dolphins: Oswald et al. (2008) found many significant differences between common and striped dolphins in the Mediterranean. By contrast, correct classification of ETP whistles to species was not significantly greater than chance for these species (χ^2 test, $p = 0.37$). The introduction of slopes variables in our classification method, enabled by a fine resolution contour analysis, led to more significant variables to differentiate the species, in particular the max negative and beginning slope. Slope variables were well represented in principal components and the beginning slope made an important contribution to the second axis of the discriminant function. Our discriminant model was efficient to classify the striped dolphin test set.

The greater difference between whistle repertoire was found between the striped and common dolphins (nine variables out of 15), and the lesser was found between Risso's and striped dolphins (five different variables). Consequently the whistle repertoire of striped and Risso’s dolphin were not discriminated with our statistical analysis based on contours. However, the latter species can easily be acoustically identified on the basis of its pulsed sounds emissions, the analysis of which was not included in our program. Roch et al. (2007) used a gaussian mixture of cepstral features to include the different categories of sounds in their classification of four delphinids.

Differences in whistle repertoires

One major finding was that striped and common dolphins in the Mediterranean Sea could be discriminated while they could not in the Eastern Tropical Pacific (Oswald et al., 2003; 2007). Discriminant function analyses indicated that correct classification was significantly greater than chance (χ^2 test, $\alpha = 0.05$) when classifying whistles of the same species to study area (Oswald et al.; 2008). We hypothesized that the degree of sympatry (low in the ETP) may cause the repertoire of both species to be similar in the ETP. On another hand, a high degree of sympatry may eventually cause species repertoirea to be more distinct compared to another species, in order for individuals to recognize conspecifics. Within a species, killer whale pods adopt different pulsed call repertoirea as to identify different vocal clans.

Because we first selected striped dolphin whistles from the northwestern Mediterranean (north of 41°N) and common dolphin recordings came mainly from the southwestern basin (south of 41°N) and Tyrrhenian Sea, the degree of sympatry between both populations may be expected to be low. But our striped dolphin test set, which was recorded in the SW basin, was equally well discriminated from the common dolphin whistle repertoire. The opportunity of both species to form mixed aggregations is higher in the SW basin, notably in the Alboran Sea, than elsewhere. And the test set was equally well discriminated, compared to the common dolphins.

Risso's dolphins is a wide ranging nomadic species in the Mediterranean Sea, which probably meets both striped and common dolphins on a regular basis. Our Risso’s dolphin whistles came from widely spaced locations (Figure 2) and its repertoire was found to be closer to that of striped dolphins than to common dolphins.

The limited cases available for our study did not permit to evidence the influence of sympatry on repertoire divergence.

Introduction of additional species

Other Mediterranean species or sub-populations may be included in the whistle comparison model, as well as samples from the eastern Atlantic Ocean. This would help to figure whether populational or species specific differences are more pregnant, given an ecological context. In the Mediterranean, the most obvious candidate among pelagic species is the pilot whale, which is better characterized on the field by its pulsed calls. Including the pulsed call structure into our present methodology is a future development. The additional analysis of bottlenose dolphin whistles, a coastal species in the Mediterranean, is currently being implemented. The introduction of both species in our model would enable it to classify every whistle recorded in the Mediterranean Sea, which would make possible the further development of a real-time acoustic survey system.

Conclusion

Our research is connected to two major issues : first, in future acoustic survey systems, it is of primary importance to discriminate the different odontocete species that are recorded but not visually checked. Passive Acoustic Monitoring methods are being increasingly used to mitigate the effect of adverse anthropogenic activities. Second, it is a scientific challenge to understand how and why species or population repertoires are driven closer or farther one from each other.

References

Gannier A., 2005. Summer Distribution and Relative Abundance of Delphinids in the Mediterranean Sea. *Rev. Ecol. (Terre Vie*) 60(3): 223-238.

Oswald J.N., Barlow J. & Norris T. F., 2003. Acoustic identification of nine delphinid species in the eastern tropical Pacific ocean. *Mar. Mamm. Sci.* , 19 (1) : 20–37.

Oswald J.N., Rankin S., Barlow J. & Lammers M.O., 2007. A tool for real-time acoustic species identification of delphinid whistles. *J. Acoust. Soc. Am.* , 122 (1) : 587-595.

Oswald J.N., Gannier A., Rankin S., Fuchs S. & Barlow J., 2008. Differences in whistle characteristics of two delphinid species in the eastern tropical Pacific Ocean and Mediterranean Sea. *In press*.

Roch M. A., Soldevilla M. S., Burtenshaw J. C., Henderson E. E. & Hildebrand J. A., 2007. Gaussian mixture model classification of odontocetes in the Southern California Bight and the Gulf of California, *J. Acoust. Soc. Am.* , 121 (3) : 1737–1748.

Tables and Figures

Figure 1: Locations of recordings used for the classification study. ● : *Grampus griseus* ; ▲ : *Delphinus delphis* ; ■: *Stenella coeruleoalba* of NW basin; ⬟: *Stenella coeruleoalba* of SW basin.

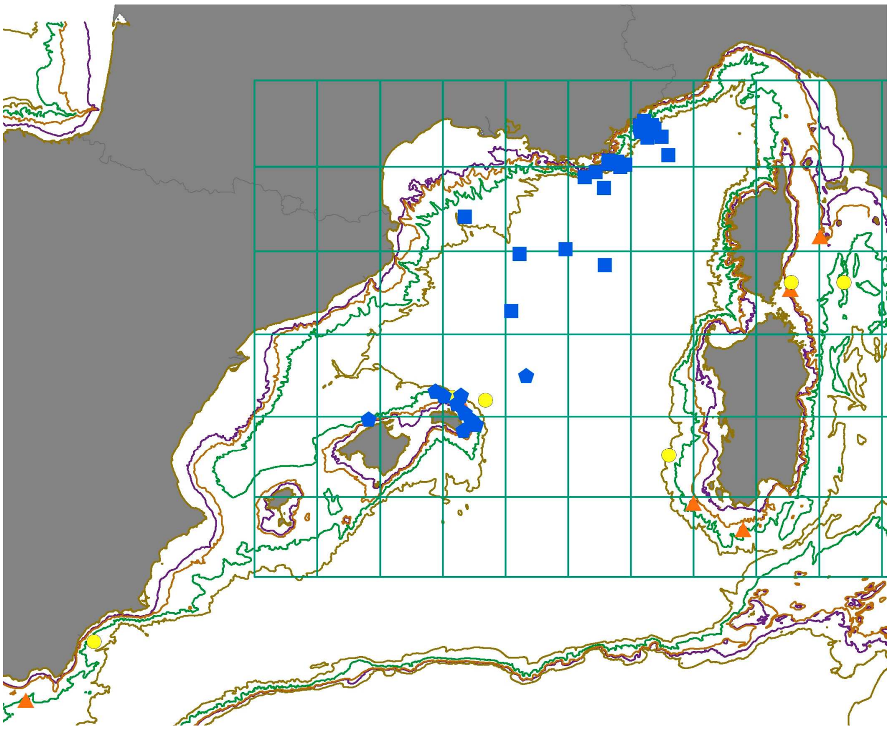

Figure 2: Principal Components Analysis on axes 1 and 2 showing the relative coordinates of the three species.

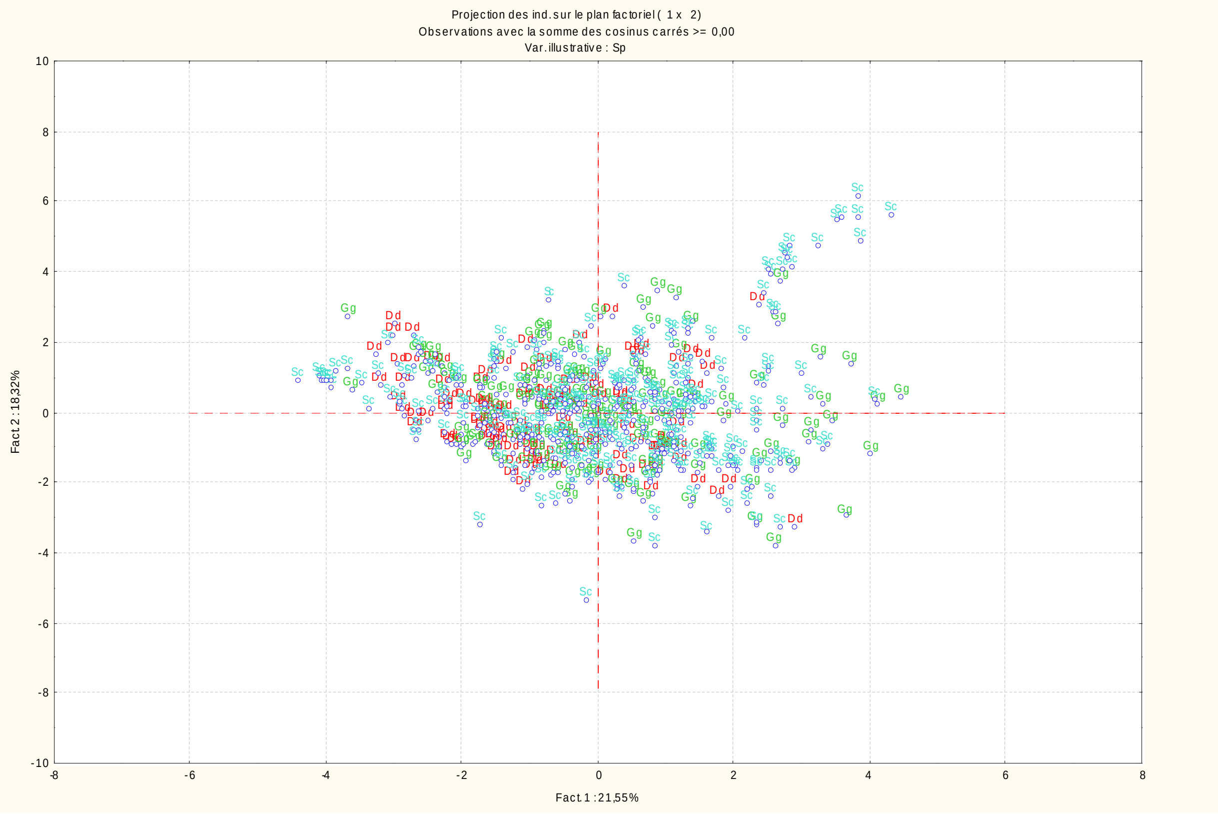

Table 1: Pairwise comparison of 15 variables for the three species. Dd = *Delphinus delphis*, Gg = *Grampus griseus* and Sc LP = *Stenella coeruleoalba* of NW basin.

Test probabilities are listed. Stars indicate significant differences at 95% confidence.

Variables	**Species pair comparison**			**Test**
	Dd/Gg	**Dd/Sc LP**	**Gg/Sc LP**	
Duration	p<0,001 *	p=0 *	p<0,02 *	Mann-Whitney
Number of harmonics	p<0,05 *	p<0,05 *	p<0,05 *	Percentages
Beginning frequency	p=0,15	p<0,01 *	p=0,00 *	Mann-Whitney
Ending frequency	p=0,63	p=0,49	p=0,84	Mann-Whitney
Minimal frequency	p=0,18	p<0,001 *	p<0,05 *	Mann-Whitney
Maximal frequency	p<0,001 *	p=0,00 *	p<0,05 *	Mann-Whitney
Mean frequency	p=0,96	p=0,18	p=0,26	Mann-Whitney
Frequency range	p<0,001 *	p=0,00 *	p<0,002 *	Mann-Whitney
Beginning slope (3 pts)	p<0,01 *	p=0,00 *	p=0,27	Mann-Whitney
Ending slope (3 pts)	p=0,52	p<0,01 *	p=0,06	Mann-Whitney
Beginning slope (7 pts)	p<0,001 *	p=0,00 *	p=0,29	Mann-Whitney
Ending slope (7 pts)	p=0,38	p<0,02 *	p=0,15	Mann-Whitney
Maximal slope	p=0,19	p=0,64	p=0,35	Mann-Whitney
Minimal slope	p<0,05 *	p=0,00 *	p=0,06	Mann-Whitney
Number of extrema	p<0,001 *	p<0,02 *	p=0,40	Mann-Whitney

Table 2 : Classification percentage using the discriminant model. Dd = *Delphinus delphis*, Gg = *Grampus griseus* et Sc LP = *Stenella coeruleoalba* of NW basin.

	% classified as		
	Dd	**Gg**	**Sc LP**
Dd	70,83	8,33	20,83
Gg	22,15	32,91	44,94
Sc	11,19	12,27	76,53