



# Social networks of bottlenose dolphins *Tursiops truncatus* in Cardigan Bay, Wales

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**Introduction:** The social structure of a population is a fundamental component of its biology and ecology. We employed network analytical techniques developed for the analysis of human sociality to construct and investigate bottlenose dolphin social networks in Cardigan Bay. A preliminary study on epidermal skin abnormalities (lesions) was conducted from the social network perspective.

**Methods:** A Half Weight Index (HWI) was utilized as a measure of association, and HWI cut-off technique used to define preferred companionships. The following network properties were investigated: average path length, clustering coefficients and centrality measures, e.g. degree of betweenness. The Girvan-Newman algorithm which calculates betweenness values was used to detect natural divisions within the network. Modularity index Q was used to detect the best division. The level of assortative mixing by sex and degree was measured using assortativity coefficient. Calculations of HWI were performed using Socprog. Networks were constructed, and the properties calculated using Ucinet; the networks were drawn using Net Draw. The prevalence & occurrence of skin lesions in individuals from the 2006 network was investigated in the relation to the individual's position in the network. Presence/absence of the lesion was determined from photos of the dorsal fin & back of the dolphin. The categorization was adapted from Wilson *et al.* (1997)

**Results:** The pooled data social network for the 5-yr period was moderately dense with a high number of direct ties among individuals ( average  $k=19.88$  max  $k=53$ ). Any two dolphins in this network could be connected through two others ( $l=2.11$ ) (Table 1). The 2006 network showed low but significant assortativity by sex while divisions in the pooled data and 2005 network may have been influenced by degree of homophily. The first maxima of  $Q=0.348$  was achieved after removal of 40% of individuals with the highest betweenness, and the network was broken into 7 components (Fig.1)

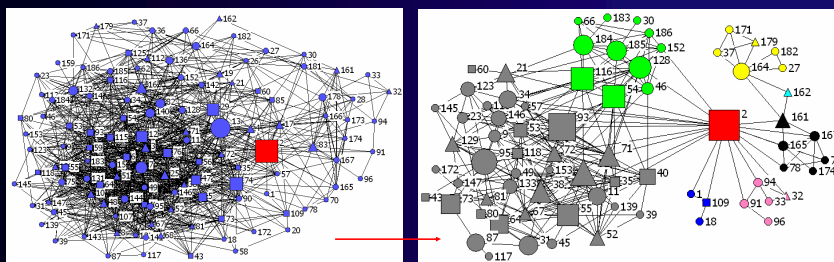


Fig.1. Pooled data network (2001-06) & the division of this network into components. Females are represented as up-triangles, males as squares, individuals of unknown sex as circles. Vertex number indicates dolphin ID, vertex colour group membership. The size of each symbol shows the level of betweenness. Individual #2 (red square) had the highest betweenness scores within the network.

Year	<i>n</i>	<i>m</i>	<i>c</i>	<i>l</i>	<i>k</i>	<i>rs</i>	<i>rd</i>
2003	63	614	0.642	2.27	9.8	-0.081	-0.328
2004	77	870	0.636	2.67	11	0.028	0.116
2005	60	436	0.762	2.96	7.3	-0.124	0.252
2006	88	812	0.691	2.75	9.2	0.113	0.028
2001-06	125	2486	0.555	2.11	20	-0.055	0.22

Table 1. Network statistics for Cardigan Bay bottlenose dolphin annual social networks, and a 5-yr pooled data social network, 2001-06; *n* is the number of vertices, *m* the number of edges, *c* the clustering coefficient, *l* the average shortest path between the vertices in the network, *k* the degree (connectivity) of the vertex, *rs* – the assortativity coefficient by sex, and *rd* the assortativity coefficient by degree.

Skin lesions were categorized, & prevalence examined, in relation to the topology of individuals in the 2006 network (Fig.2a). 61% of all individuals had at least one lesion type. “Yellow” symbols (Fig.2a) had the most dolphins with lesions (75%), with black fringe spots (BFS) showing highest frequency (43%) (Fig.2b). 60% of all cloudy lesions (CL) were found in the area with “Red” symbols, while 54% of all white patches were present in the area with “Grey” symbols. The distribution of individuals with BFS and CL is shown in Fig. 2 (b).

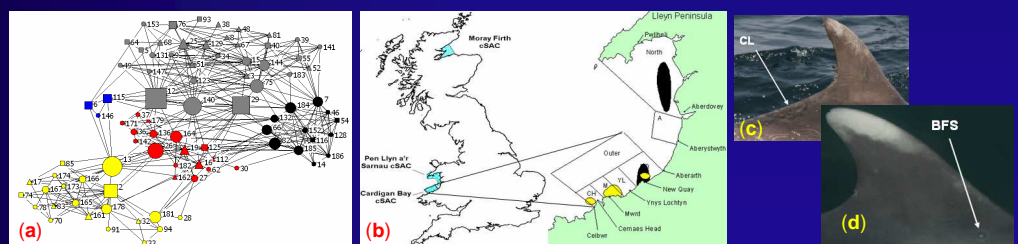


Fig.2. a) Divisions in the 2006 social network, based on betweenness. Vertex number indicates dolphin ID; vertex colour indicates group membership. Females are presented as up-triangles, males as squares, individuals of unknown sex as circles. The size of each symbol shows the level of betweenness of each vertex. (b) Distribution of individuals having skin lesions in the 2006 network. Black kernels represent centres of activity for dolphins with black-fringe spots in the “Yellow” component; yellow kernels show areas where dolphins from the “Red” component with cloudy lesions were most often encountered. (c) Photograph showing a cloudy lesion (dolphin # 040); (d) Photograph showing a black fringe spot (dolphin #032)

## Conclusions:

- Based on the association evidence, and comparing our findings to the patterns observed in other bottlenose dolphin communities, it is likely that the Cardigan Bay bottlenose dolphin population can be regarded as a fission-fusion social system with a large number of bonds, and many redundant paths for the transfer of information.
- The variability of network properties in annual networks may indicate the dynamics of relationships.
- A non-random distribution of different types of skin disorders within the components of the network pointed to the need for further research and more detailed investigation.