

## Mariana Degradi

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Date sent: **Wed, 8 Aug 2012 09:35:22 -0400 (EDT)**  
From: **mmsci@megalink.net**  
To: **degrati@cenpat.edu.ar**  
Copies to: **marinemammalscience@gmail.com**  
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08-Aug-2012

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Sincerely,

Daryl J. Boness  
Editor  
Marine Mammal Science

1      **Sequential foraging of dusky dolphins with an inspection of their prey distribution**

2  
3      Mariana Degradi<sup>1,2</sup>, Silvana L. Dans<sup>1,2</sup>, Griselda V. Garaffo<sup>3</sup>, Ariel G. Cabreira<sup>4</sup>, Federico  
4                                  Castro Machado<sup>4</sup> and Enrique A. Crespo<sup>1,2</sup>

5  
6  
7                  <sup>1</sup> Centro Nacional Patagónico (CONICET), Bvd. Brown 2915 (9120), Puerto Madryn,  
8    Chubut, Argentina.

9  
10                <sup>2</sup> Universidad Nacional de la Patagonia, Boulevard Almirante Brown 3600, CP (9120) Puerto  
11    Madryn, Chubut, Argentina.

12  
13                <sup>3</sup> Universidad Nacional de Mar del Plata, Funes 3600, Mar del Plata (7600), Argentina.

14  
15                <sup>4</sup> Instituto Nacional de Investigación y Desarrollo Pesquero, Paseo V. Ocampo N° 1, Mar del  
16    Plata (7600), Argentina.

26 **ABSTRACT**

27

28         The aim of this work was to analyze the sequential foraging behavior of dusky dolphins  
29 (*Lagenorhynchus obscurus*). Foraging sequences were defined when more than two feeding  
30 bouts occur with a travelling bout between them. We hypothesized that travelling costs of  
31 searching for prey patches were related to the time spent feeding on a patch. In addition, the  
32 distribution and seasonal variation of anchovy schools were studied in the area to better  
33 understand dolphins' behavior. We observed dolphins from a research vessel from 2001 to  
34 2007, and recorded their location and behavior. Anchovy data were collected during two  
35 hydro-acoustic surveys. Dusky dolphin behaviors varied seasonally; they spent a greater  
36 proportion of time travelling and feeding in the warm season (Kruskal-Wallis:  $H = 172.07$ ,  $P$   
37  $< 0.01$ ). During the cold season dolphin groups were more likely to exhibit diving behavior  
38 and less surface feeding. We found a positive correlation between searching and foraging  
39 time ( $r = 0.88$ ,  $P = 0.019$ ), suggesting that the costs associated with searching were  
40 compensated by an increase in the energy intake during the foraging bout. There was an  
41 association between dusky dolphin and anchovy distribution, in that they co-varied spatially  
42 and seasonally.

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46 Key words: foraging strategy, foraging sequence, dusky dolphins, anchovies, Patagonia.

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## 51 INTRODUCTION

52 To cope with the high uncertainty associated with prey distribution and abundance,  
53 marine top predators have developed complex foraging strategies in heterogeneous  
54 environments (Russell *et al.* 1992, Viswanathan *et al.* 1996, Fauchald 1999, Pinaud and  
55 Weimerskirch 2005, Benhamou 2007). Foraging theory predicts that individuals, when  
56 searching, selecting, and eating food, choose those behaviors that allow them to get the  
57 greatest benefit with minimal effort and risk (Stephens and Krebs 1986, Krebs and Davies  
58 1993). Within this theoretical framework, Charnov (1976) developed the marginal value  
59 theorem or the patch model. This model assumes that the forager encounters patches of food  
60 one after the other (sequential encounter) assuming that foraging consists of many repetitions  
61 of the following sequence: search-encounter-decide. Within this model the individual should  
62 decide how long to stay in a patch to maximize the long term average rate of energy intake.  
63 Considering some restrictive assumptions (all patches have the same gain function and search  
64 costs are zero), the marginal value theorem shows that the optimal residence time depends on  
65 travel to the patch time. When travel time is long, residence time is long and vice versa  
66 (Stephens and Krebs 1986).

67 The relationship between search patterns and the distribution of food has rarely been  
68 documented for large free-ranging animals (Ward and Saltz 1994, Mårell *et al.* 2002). In  
69 marine ecosystems, the distribution of fish prey is poorly known at small temporal and spatial  
70 scales, which makes the comparison between predator searching effort and prey density  
71 extremely difficult. Prey distribution and dynamics have strong effects on the foraging  
72 behavior of marine predators. The amount of work, and therefore energy expenditure that an  
73 animal invests in locating prey likely varies as a function of the energy content, availability,  
74 and location of the individual prey items (Stephens and Krebs 1986). Prey availability varies  
75 as a function of its density and its distribution in the environment.

76 Experiments that manipulate prey resources are difficult to carry out in the pelagic  
77 environment, therefore spatial and temporal variation in prey and predator distributions can be  
78 examined to provide insights into their interactions (Benoit-Bird and Au 2003, Benoit-Bird *et*  
79 *al.* 2004). Analysis of predator behaviors and prey distribution can improve our understanding  
80 of the foraging strategies of marine predators. Entire foraging sequences are relatively easy to  
81 obtain for terrestrial animals (*e.g.*, Clarke *et al.* 1995), allowing researchers to discriminate  
82 between feeding and searching behaviors. Among marine animals, foraging sequences have  
83 been more difficult to observe (but see Miller *et al.* 1995, Nowacek 2002).

84 Dusky dolphins (*Lagenorhynchus obscurus*) are small delphinids that inhabit select  
85 areas of coastal temperate waters in the southern hemisphere. They are semi-pelagic top  
86 predators that exhibit great behavioral flexibility in foraging. Off Argentina, dusky dolphins  
87 primarily feed on schooling southern anchovy (*Engraulis anchoita*), which they hunt  
88 cooperatively at the surface, during the day (Würsig and Würsig 1980, Degradi *et al.* 2008).  
89 However, other species, such as juvenile common hake (*Merluccius hubbsi*) and squids  
90 (Argentine short-fin squid *Illex argentinus*, Patagonian long-fin squid *Loligo gahi* and South  
91 American long-fin squid *Loligo sanpaulensis*), were also recorded in their diet (Koen Alonso  
92 *et al.* 1998, Romero *et al.* 2012). Dolphin groups at times join together during foraging, with  
93 feeding lasting for several hours.

94 As part of a long-term research program in Golfo Nuevo, northern Ptgonia, behavioral  
95 sequences of dusky dolphins foraging during daylight hours were described (Vaughn *et al.*  
96 2010). Within these sequences, dolphins alternate feeding bouts with travelling bouts in long  
97 sequences. This behavior may be a foraging tactic related to prey distribution, whereby  
98 dolphins find a prey patch, feed on it, and then move to the next patch.

99 The aim of this work was to analyze the sequential foraging behavior of dusky dolphins.  
100 We hypothesized that travelling costs of searching for prey patches were related to the time

101 spent feeding on a patch. This hypothesized relationship was tested at two spatial scales: 1) At  
102 a small spatial scale: if travelling bouts within the foraging sequence are searching bouts, one  
103 might expect that, in a given sequence, the more time dolphins spend travelling, the more time  
104 they will spend feeding subsequently. 2) At a larger spatial scale: dolphins move to areas  
105 with high concentrations of prey and then start feeding. Based on these assumptions, we  
106 hypothesized that the more time dolphins spent in a travelling bout before the foraging  
107 sequence started, the longer the sequence duration would be. In addition, the distribution and  
108 seasonal variation of anchovy schools were studied in the area to better understand dolphin  
109 foraging sequences.

## 110 **METHODS**

### 111 *Study area*

112 Golfo Nuevo (42°20' - 42°50'S, 64°20' - 65°00'W; Fig. 2) is located in northern  
113 Patagonia, Argentina. It is surrounded by Península Valdés, a protected area that was declared  
114 a World Heritage Site by the UNESCO (United Nations Educational, Scientific, and Cultural  
115 Organization) in 1999. The Gulf is a semi-closed basin approximately 70 km long and 60 km  
116 wide with a total area of 2,500 km<sup>2</sup>. The average depth is 80 m with a maximum depth of 184  
117 m (Mouzo *et al.* 1978). The mouth of the Gulf is 16 km long and connects to the Atlantic  
118 Ocean by shallow waters with an average depth of 44 m (Mouzo *et al.* 1978).

119 We define two seasons (cold and warm) in relation to the sea water temperature. During  
120 the warm season (November to April), Golfo Nuevo is strongly stratified both vertically  
121 (18°C at surface and 11°C at bottom) and horizontally, with lower temperatures occurring  
122 along the southern and northern coasts (16°C) and higher temperatures occurring in the central  
123 area of the Gulf (18-19°C). In the cold season (May to October) the water is mixed and the  
124 temperature is homogeneous both vertically (12°C both at the surface and the bottom) and

125 horizontally (11-13°C both in the line cost and in the central area of the gulf) (Rivas and Ripa  
126 1989, Garaffo *et al.* 2010).

### 127 *Dolphin data*

128 Random transects were surveyed onboard a research vessel from 2001 to 2007. Three  
129 research vessels were used: a 6 m fiberglass boat with a 50 hp outboard engine from 2001 to  
130 2003, a 7 m fiberglass boat with a 105 hp outboard engine and an inflatable boat of 6 m with a  
131 90 hp outboard engine from 2004 to 2007. One survey was completed each day between 0800  
132 and 2000. The mean duration of surveys was 5:23 ± 1 SD h:min (range = 1:30 – 9); the  
133 duration was determined by sea state and weather conditions (Beaufort sea state ≤ 3). For  
134 behavioral data collection, a group of dolphins was defined as any collection of individuals  
135 located in close proximity (<10 m) to one another (Smolker *et al.* 1992).

136 To minimize our potential impact on the dolphins' behavior, each group was  
137 approached slowly, from the side and rear, with the vessel moving in the same direction as the  
138 animals. Dolphins were followed at a constant distance of about 100 m, with minimal changes  
139 in vessel heading and speed. When a group of dolphins was sighted their size, predominant  
140 activity, and location were recorded. Groups were classified into the following arbitrary size  
141 categories: <10, 10-20, 21-50, 51-70, 71-100 and >100 individuals. The predominant activity  
142 or "behavioral state" was defined as the activity in which > 50% of group members were  
143 engaged; for our study population, typically > 90% of the animals in a group were engaged in  
144 the same activity, indicating that this form of sampling provided a robust measure of the  
145 behavior of group members. Six predominant activities, diving, feeding, milling, resting,  
146 socializing, and traveling were used to categorize behavioral state (Table 1). During  
147 behavioral sampling, group members were observed continuously as long as possible, and the  
148 predominant activity was recorded at 2 min intervals using an instantaneous sampling



149 protocol (Altmann 1974). The location of the group was also recorded every 2 min by a  
150 Global Positional System and stored as a track file.

#### 151 *Activity pattern analysis*

152 For activity patterns analyses each dolphin group-follow was considered an independent  
153 observation. Dusky dolphins are characterized by a fluid, fission–fusion society and their  
154 associations are not static over time (Markowitz *et al.* 2004). As a result, groups sighted on  
155 different days were considered distinct. When new dolphins joined the focal group or the  
156 group split, the resulting collection of individuals was considered a new group. Only one  
157 group per day was considered in the statistics analysis. Because behavior at consecutive 2 min  
158 intervals was not independent, the proportion of time spent in each of the 6 defined activities  
159 was calculated from each group-follow. The nonparametric Kruskal-Wallis test was used to  
160 assess differences in activities among cold and warm seasons. Nonparametric tests were  
161 selected because assumptions regarding normality and homogeneity of variance between  
162 samples were not met and because the existence of outliers made the median more  
163 representative than the mean for these samples (Lehner 1998).

#### 164 *Foraging sequences analysis*

165 A foraging sequence was defined by at least two feeding bouts (F) occurring with a  
166 travelling bout (T) between them, and was completed when an activity different than  
167 travelling occurred after a feeding bout. A bout was defined as a period of time in which a  
168 single behavioral state occurred (Martin and Bateson 1993). A feeding bout was distinguished  
169 as the set of consecutive 2 min intervals in which feeding was recorded as the behavioral  
170 state. In a similar way, a traveling bout was defined as the set of consecutive 2 min intervals  
171 in which traveling was recorded. The duration and distance dolphins moved during a bout and  
172 during the whole sequence were determined.

173 The relationship between time traveling and time feeding was analyzed at two spatial  
174 scales. A smaller scale was defined taking into account the distance dolphins moved during a  
175 feeding bout within a sequence (mean = 571 m, SD = 353 m,  $n = 37$ ) and a larger spatial scale  
176 was defined considering the distance dolphins moved during the whole foraging sequence  
177 (mean = 3724 m, SD = 2965 m,  $n = 37$ ). A Spearman correlation was used to test the  
178 relationship between the time in consecutive feeding and travelling bouts within a sequence,  
179 and to test the correlation between the time dolphins spent in a travelling bout before foraging  
180 (T') and the whole foraging sequence (T plus F).

#### 181 *Prey distribution data*

182 Two hydro-acoustic surveys were carried out during 2007. A total distance of 99 and  
183 120 nautical miles (nm) were surveyed during the cold season (24-29 May) and the warm  
184 season (27 Nov -2 Dec), respectively. Weather conditions deteriorated during the first survey  
185 precluding the completion of some transects.

186 The acoustic sampling consisted of systematic zigzag transects (Fig. 1). A research  
187 vessel of 7 m with a 105 hp outboard engine was used for data collection. If during the  
188 acoustic route a group of dolphins was sighted, the track was abandoned and the group was  
189 followed to record behavioral data. At the end of observations the transect was continued at  
190 the same point where it was abandoned. Acoustic data sets were obtained using a portable  
191 echo-sounder SIMRAD EY-500 operating a 38 kHz split beam transducer. The transmitted  
192 pulse duration was 1 ms and a wide bandwidth was used. The echo-sounder was calibrated  
193 with standard targets following Foote *et al.* (1987). Data were collected continuously during  
194 between 0900 and 1900 local time and then stored on digital media for future processing and  
195 analysis. Interpretation of the echogram was performed by personnel experienced in using  
196 visual echo-trace. Fish school data analysis was performed using EchoView (v.4.10.67;  
197 SonarData 2005). Anchovy school density was calculated using the echo-integration method

198 (MacLennan and Simmonds 1992). The sound scattering values (sA) assigned to anchovy  
199 were obtained from the analysis of the echograms in which regions were defined for each of  
200 the registered schools. A minimum threshold was established at -70 dB. In order to show the  
201 horizontal distribution of the echo-integration values of anchovy a ESDU (Elementary  
202 Sampling Distance Unit) was set at 0.1 nm.

203 The shape, density, and location in the water column of each school were obtained. The  
204 school boundaries were determined using the algorithm provided in the school program  
205 module (SonarData 2005). Some school descriptors were extracted, and grouped into  
206 energetic (sA), morphological (length, height, perimeter, area, volume), and bathymetric  
207 (depth) categories. All morphological measurements were corrected for beam width effects  
208 (Diner 2001). In addition, distances between the anchovy schools were calculated using  
209 Geographic Information System tools (GIS).

#### 210 *Prey and predator analysis*

211 For spatial analysis the location of dolphin groups and anchovy schools was overlapped  
212 with a grid characterized by depth data. The location of a dolphin group was considered as the  
213 position at which a group was first sighted. The whole data set of dolphin groups sighted was  
214 used (2001-2007). Anchovy data were obtained from acoustic surveys performed in 2007 as  
215 explained above.

216 A preliminary assessment of whether depth and distance from shore are independent  
217 was done using data obtained from Nautical charts (H-218, 1:110,000, Naval Hydrographic  
218 Service) (Mouzo *et al.* 1978). A grid of 1.5 x 1.5 km was constructed for the study area. A  
219 GIS was used to integrate the nautical chart with the grid. Each cell of the grid was  
220 characterized by depth and distance from shore. Mean depth was calculated by averaging  
221 values of depth. Distance from shore was calculated as distance from the central point of each

222 cell to the closest line coast. Dolphins and anchovy locations were overlapped on the grid. A  
223 Kruskal-Wallis test was used to test for statistical differences in bottom depth between  
224 dolphins and anchovy locations as well as temporal variation. In all cases, a significance level  
225 of  $\alpha = 0.05$  was used (Siegel and Castellan 1995, Conover 1999).

226

## 227 **RESULTS**

### 228 *Dolphin groups' activity pattern*

229 A total of 235 random surveys were conducted during this study (Table 2). During the  
230 whole period 263 groups were reordered. Group size varied between the seasons. During the  
231 warm season more than 40% of groups were larger than 20 animals while during the cold  
232 season they were only observed 20% of this and most of them were less than 10 individuals  
233 ( $\chi^2_5 = 11.45, P < 0.05$ ).

234 Behavioral data were recorded for 184 groups during the warm season and 45 during  
235 the cold season. Dusky dolphins showed seasonal variation in their behaviors (Kruskal-  
236 Wallis:  $H = 172.07, P < 0.01, n_{\text{warm}} = 69, n_{\text{cold}} = 26$ ). They spent a greater proportion of time  
237 travelling and feeding in the warm season, and a greater proportion of time milling and resting  
238 in the cold season (Fig. 2). Additionally, feeding at the surface decreased during the cold  
239 season ( $\chi^2_2 = 21.32, P < 0.001$ ) while feeding behaviors were almost entirely at the surface in  
240 the warm season (Fig. 3).

### 241 *Dolphin foraging sequence*

242 Forty one percent of dolphin groups that were feeding showed travelling-feeding  
243 sequences. The average duration of foraging sequences was 42 min (range = 8-134 min).  
244 Sequences contained 2-6 feeding bouts. Within a foraging sequence, there was no relationship  
245 between the duration of consecutive travelling (T) and feeding (F) bouts (Spearman rank

246 correlation:  $r = 0.068$ ,  $P = 0.58$ ,  $n = 70$ ). However, a positive correlation was found between  
247 time spent travelling before a foraging sequence (T') and time spent in the complete foraging  
248 sequence (Spearman rank correlation:  $r = 0.88$ ,  $P = 0.019$ ,  $n = 6$ , Fig. 4).

#### 249 *Anchovy's schools and their relation with dolphins' spatial distribution*

250 Although anchovy data came from one year we assumed that the variation among years  
251 was negligible. It is expected that anchovy distribution changes with sea surface temperature  
252 (sst) and concentration of chlorophyll *a* (chlorophyll) (Bakun and Parrish 1991, Hansen *et al.*  
253 2001). In order to check for any possible variation in these environmental variables along the  
254 study period, sst and chlorophyll data were inspected. Mean sst for each month was extracted  
255 from satellite images without clouds (NOAA Advanced Very High Resolution Radiometer  
256 <http://www.conae.gov.ar>) at a spatial resolution  $1.1 \text{ km}^2$  and from the Giovanni online data  
257 system, developed and maintained by the NASA GES DISC. In addition, mean concentration  
258 of chlorophyll *a* ( $\text{mg}/\text{m}^3$ ) data for each month were extracted from the Giovanni online data  
259 system from 2001 to 2007. SeaWiFS images were used by this source. The monthly variation  
260 pattern of sst was kept over the years (ANCOVA,  $P_{\text{months}} < 0.001$  and  $P_{\text{years}} > 0.84$ ) as were  
261 chlorophyll values. Neither showed changes among the study period (ANCOVA,  $P_{\text{months}} >$   
262  $0.40$  and  $P_{\text{years}} > 0.37$ ). Therefore we did not expect large changes in anchovy distribution  
263 among the years.

264 Anchovies were detected in both hydroacoustic surveys, 160 schools during the warm  
265 season and 441 during the cold season, which were clumped in different areas of the gulf. The  
266 areas where dolphins and anchovies were sighted are shown in figure 1. Although the area  
267 covered by the surveys was larger, dolphin groups were mostly found in the area covered  
268 during hydroacoustic surveys.

269 The analysis of the schools showed that during the cold season anchovy schools were  
270 larger and located deeper in the water column (Table 3). In addition, anchovy schools were  
271 acoustically denser (sA) and were found closer to each other in the warm than in the cold  
272 season (Table 3).

273 Spatial analysis showed that dolphins and anchovy locations varied between seasons.  
274 Both predator and prey were located in deeper waters during the cold season (Kruskal-Wallis:  
275  $H = 145.3, P < 0.001$ , Fig. 5). We obtained the same results if we only used a data set of  
276 dolphins sighting in the same year that acoustic surveys were carried out (Kruskal-Wallis:  $H =$   
277  $114.5, P < 0.001$ ). Depth and distance from shore are correlated variables ( $r = 0.82, P <$   
278  $0.001$ ), therefore we only analyzed data relative to depth. During this season, dolphins were  
279 located in areas 68.3 m deep, 4.6 km from shore, while anchovies were located in areas 85 m  
280 deep and 5 km from shore. During the warm season dolphins were located in waters of 36.1 m  
281 deep and 2.5 km from shore while anchovies were located in waters 55 m deep and 3.7 km of  
282 distance from shore (Fig.6).

283

## 284 **DISCUSSION**

285 Seasonal variation in activity budgets was observed for dusky dolphins. Dolphins spent  
286 a greater proportion of time travelling and feeding at the water surface during the warm  
287 season, while they spent a greater proportion of time diving during the cold season. The only  
288 data available on prey distribution obtained in the present work were from 2007 and hence  
289 our results cannot be generalized to the whole study period. Results obtained showed that  
290 anchovies and dolphins moved to deeper waters in the cold season, at the same time  
291 anchovies are located deeper in the water column. This result suggests that dolphins are  
292 following their prey, moving accordingly their location. During the cold season anchovy were

293 concentrated in a small portion of the Gulf (in front of Puerto Madryn coast), while during the  
294 warm season they were distributed over a larger area (along the southwest cost of the Gulf,  
295 Fig. 1). These results were concordant with the habitat use pattern described for dusky  
296 dolphins (Garaffo *et al.* 2007, 2010). During the warm season dusky dolphins used larger  
297 areas, staying less time in a particular location, but for the rest of the year, they were more  
298 concentrated in a smaller area.

299         Although the main feeding strategy of dusky dolphins in Patagonia is surface feeding,  
300 we would expect that during the cold season dolphins would use alternative feeding tactics  
301 that allow them to get more energy at lower costs. An association between diving and milling  
302 behavior was observed during this season (Degradi *et al.* 2012) suggesting that feeding at  
303 depth could be this alternative strategy; however, the energy budgets that these activities  
304 represent in the survival and reproduction of each individual is unknown. Marine mammals  
305 that feed within the water column must interrupt foraging activity to go to surface to breathe,  
306 decreasing the time available for food intake. Feeding at the surface would be advantageous to  
307 dolphins, but in situations where prey are not accessible at the surface, an alternative tactics  
308 must be used. In Admiralty Bay (New Zealand), dusky dolphins exhibit temporal changes in  
309 their feeding tactics, possibly in response to a change in prey species or behavior. From  
310 August to November dolphins herd small schools of fish to the surface, while from May  
311 through July, they feed on mobile prey at depth (Vaughn *et al.* 2007). Some of these same  
312 dolphins also forage at night on the deep scattering layer (Benoit-Bird *et al.* 2004, Markowitz  
313 *et al.* 2004)

314         According to foraging theory, it is expected that patch residence time depends on travel  
315 time (Stephens and Krebs 1986). When we considered an entire sequence as a foraging  
316 episode (F plus T bouts), we found a positive correlation between searching (T') and foraging  
317 time. On a larger spatial scale dusky dolphins move to areas of large concentration of prey.

318 Within such broad scale areas, dolphins start foraging, and then alternate feeding and  
319 travelling bouts. In this case, the time spent by dolphins in travelling would be part of the  
320 handling time of prey or the displacement between schools within the foraging area.  
321 Therefore, there is no single characteristic scale that describes foraging tactics, but rather  
322 several scales that may reveal different processes (Fauchald *et al.* 2000).

323 In Golfo Nuevo dusky dolphin group size changed with the season. Larger groups were  
324 found in the warm season. This variation could be a function of the foraging tactic in response  
325 to the prey distribution. Dusky dolphins are group foragers and the amount of energy gained  
326 will depend on the number of individuals into the group. Having to sharing food resources  
327 with other group members causes within-group feeding competition, which reduces the  
328 foraging success of individuals within the group (Janson 1988, Janson and van Schaik 1988).  
329 Within group feeding competition increases with increasing group size (Janson and  
330 Goldsmith 1995, Steenbeek and van Schaik 2001). However, individuals in a group have  
331 some benefits in terms of the efficient discovery of food patches (Clark and Mangel 1986)  
332 and protection from predators. In addition, Würsig and Würsig (1980) reported that dusky  
333 dolphin appear to have more success when working together driving schooling fish to the  
334 surface, since they can contain “prey balls” more effectively. These authors also reported that  
335 dusky dolphin groups pay close attention to each other, with one group finding prey and  
336 another group joining in (Würsig and Würsig 1980). During our study, we observed the same  
337 pattern, but as explained in the methodology, when new dolphins joined the focal group or the  
338 group split, the resulting collection of individuals was considered a new group in the  
339 statistical analyses. In our work, foraging sequence data were not analyzed in relation to  
340 group size because of the small sample size. However our results help to better understand  
341 foraging behaviors of pelagic dolphins and serve as a starting point for the more complex  
342 studies about the functional relationship between predator performance and prey distribution



343 and abundance. This is critical to understanding the dynamics of trophic interactions and  
344 pathways of energy flow in pelagic marine ecosystems.

345

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481 **Table 1.** Behavioral states or activities of dusky dolphin groups in Golfo Nuevo.

Activity	Description
Feeding	<p>Dolphins move fast, diving and emerging in all directions. At times it is possible to see dolphins harassing fish, fish jumping out of water, and marine birds like terns, gulls, albatrosses, giant petrels, shearwaters, cormorants, jaegers, and others, feeding at the same time. Dolphins move fast but the group does not change location.</p> <p>Two types of feeding: <i>feeding in sequences</i> (F), when a feeding bout occurred in a foraging sequence and <i>isolated feeding</i> when a feeding bout occurred before or after a non-travelling activity.</p>
Traveling	<p>Persistent movement, with all group members swimming in the same direction.</p> <p>Two types of travelling bouts: travelling bouts following any activity except feeding (T'), and travelling bouts between two feeding bouts (T)</p>
Socializing	<p>Frequent interactions between 2 or more individuals, usually in the form of body contact accompanied by high-speed movements, frequent changes in direction. Aerial displays such as leaps, tail-over-head leaps, backslap, headslaps, and tailslaps are common.</p>
Resting	<p>Low level of activity, with individuals remaining stationary, at times floating motionless on the surface, with occasional slow forward movement.</p>
Milling	<p>Low-speed movement with frequent changes in direction, resulting in little overall directional movement by the group.</p>
Diving	<p>Entire dolphin group submerged under water in a coordinated movement, presumably encountering prey.</p>

483 **Table 2.** Summary of the effort during the dolphin groups survey in Golfo Nuevo.

Year	Survey hours	Hours with dolphins	N° of groups
2001	132	56	59
2002	148	20	55
2003	133	25	39
2004	143	29	39
2005	221	32	74
2006	89	13	27
2007	135	13	19

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485 **Table 3.** Mean values of each anchovy schools descriptors obtain in Golfo Nuevo during the  
 486 surveys. P values are the probabilities obtain from the comparison of two independent  
 487 samples (Mann-Whitney U test, cold vs warm season).

School descriptor	Mean value		Unit	<i>P</i>
	Cold season	Warm season		
Length	41.68	29.41	m	0.0151
Height	10.99	10.13	m	0.1507
Perimeter	206.78	149.30	m	0.0246
Area	308.89	241.88	m <sup>2</sup>	0.1730
Volume	2,570.39	2,298.18	m <sup>3</sup>	0.3677
School depth	52.15	23.78	m	0.0001
sA	618	1340,00	m <sup>2</sup> /nm <sup>2</sup>	0.0001
Distance	742,00	286,00	m	0.0001

488 **FIGURE LEGENDS**

489 Figure 1. Dolphin and anchovy locations recorded during a) cold season and b) warm season,  
490 in the study area. Black triangles are dolphin sightings between 2001 to 2006 and white  
491 squares are dolphins sightings of 2007; size of gray circles is proportional to the square root  
492 of the sound scattering values (sA) assigned to anchovy schools; black lines show the transect  
493 followed during anchovy surveys and gray dotted lines represent the random transects  
494 travelled during dolphin surveys.

495 Figure 2. Proportion of time dusky dolphins exhibited different behaviors during the seasons.  
496 Bars represent mean values; lines represent standard errors for these means. Significant  
497 differences are indicated by asterisks.

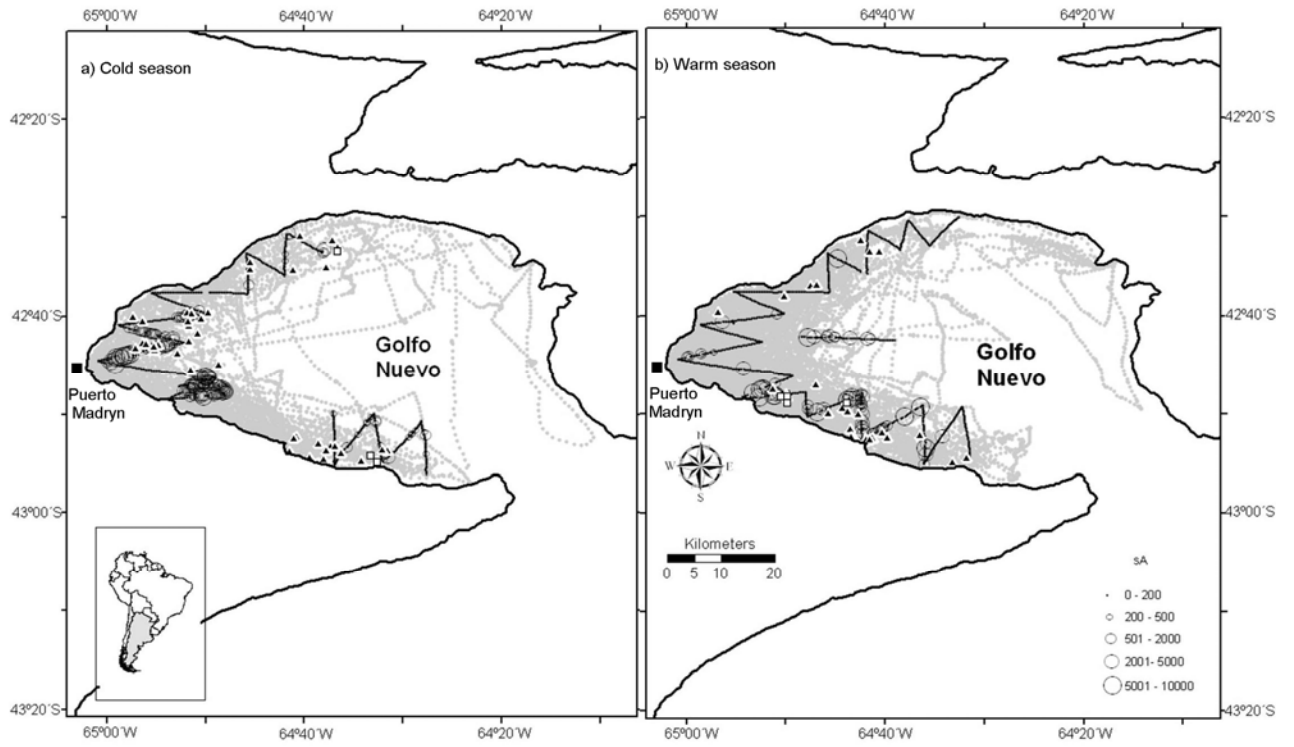
498 Figure 3. Proportion of dolphin groups recorded in different foraging behaviors during warm  
499 and cold seasons.

500 Figure 4. Relationship between the time that dusky dolphin groups spent travelling before a  
501 sequence, and time spent foraging (considering the whole sequence,  $n = 6$ ).

502 Figure 5. Bottom depth where dolphin groups and anchovy schools were found during both  
503 seasons.

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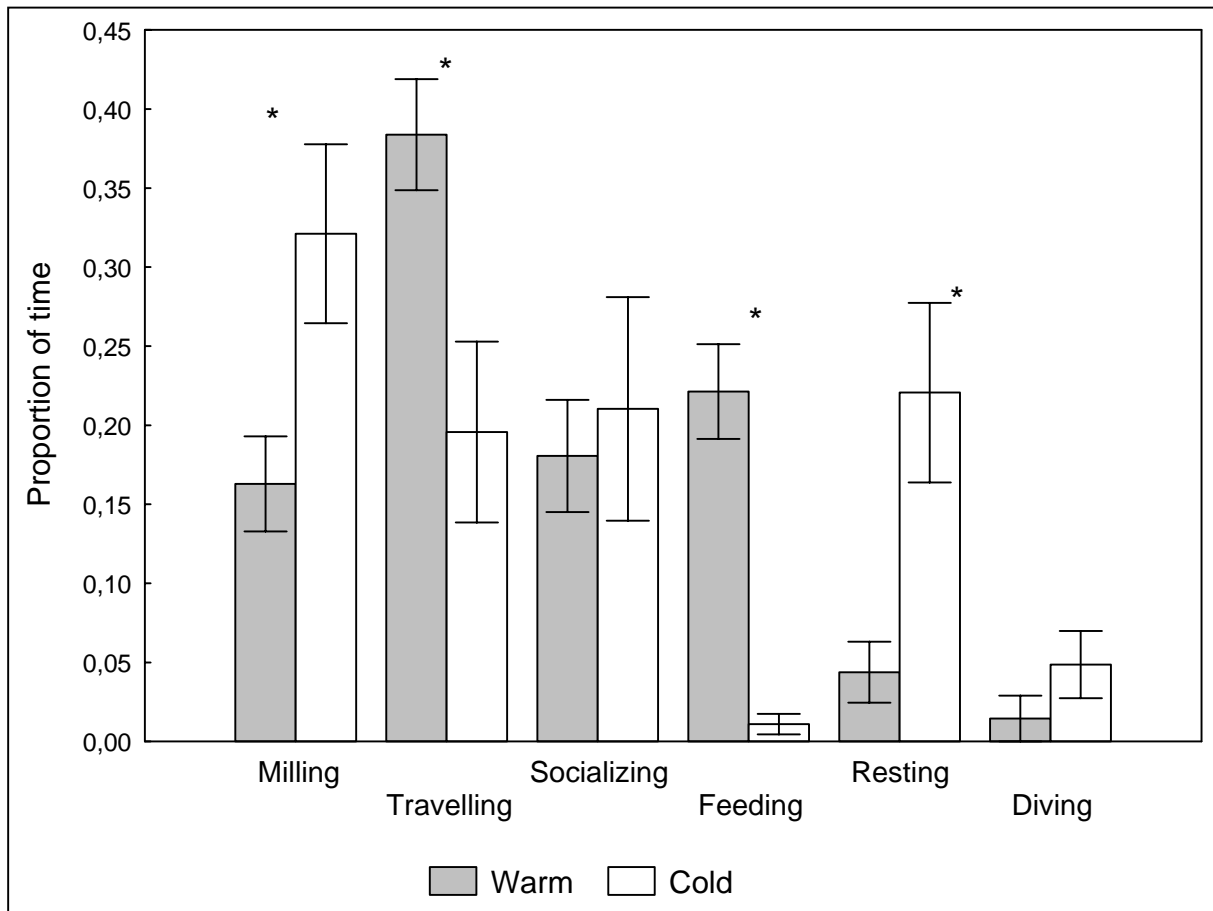


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Figure 1

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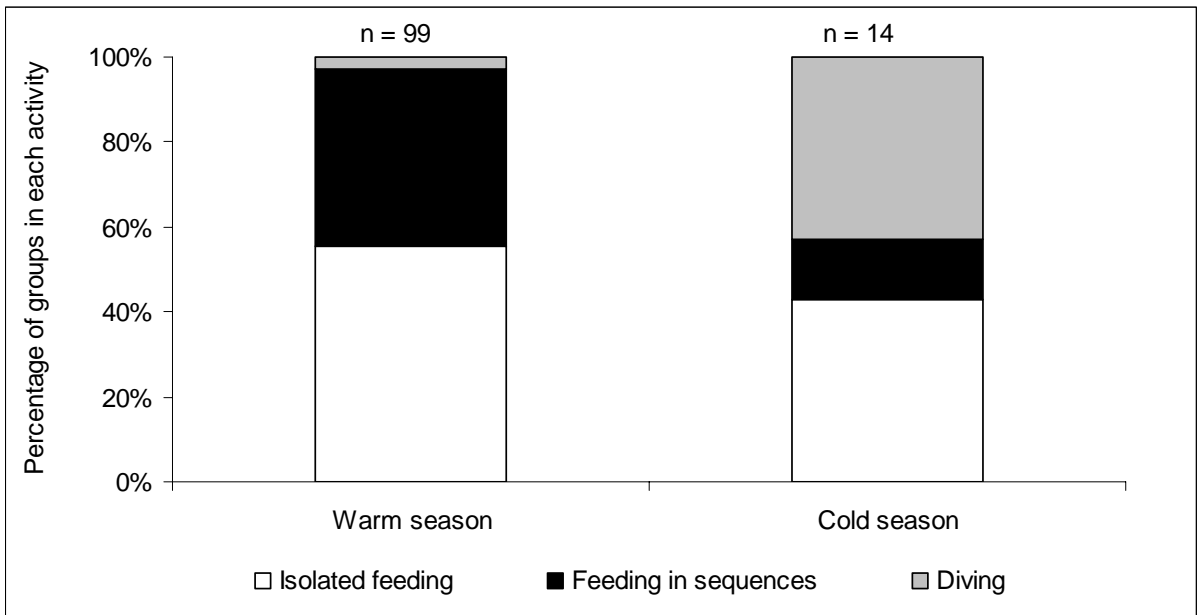


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Figure 2

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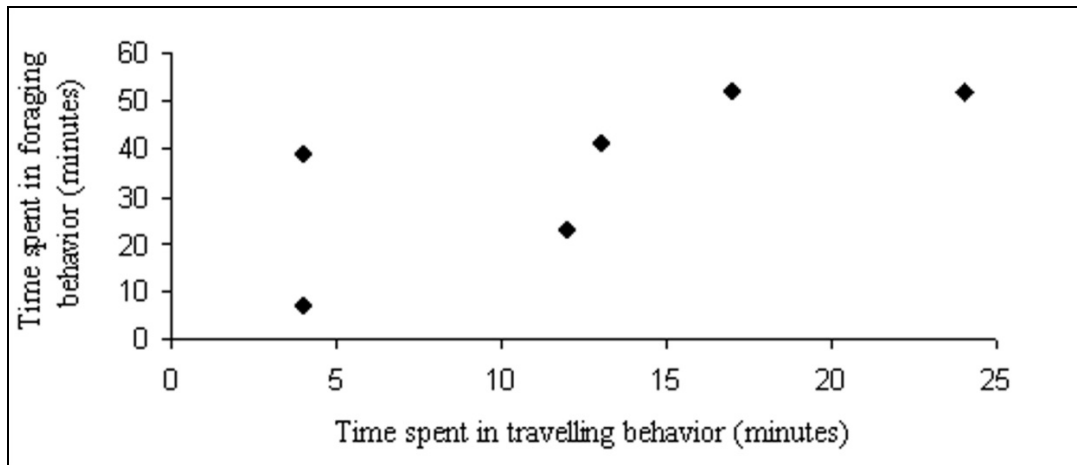


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Figure 3

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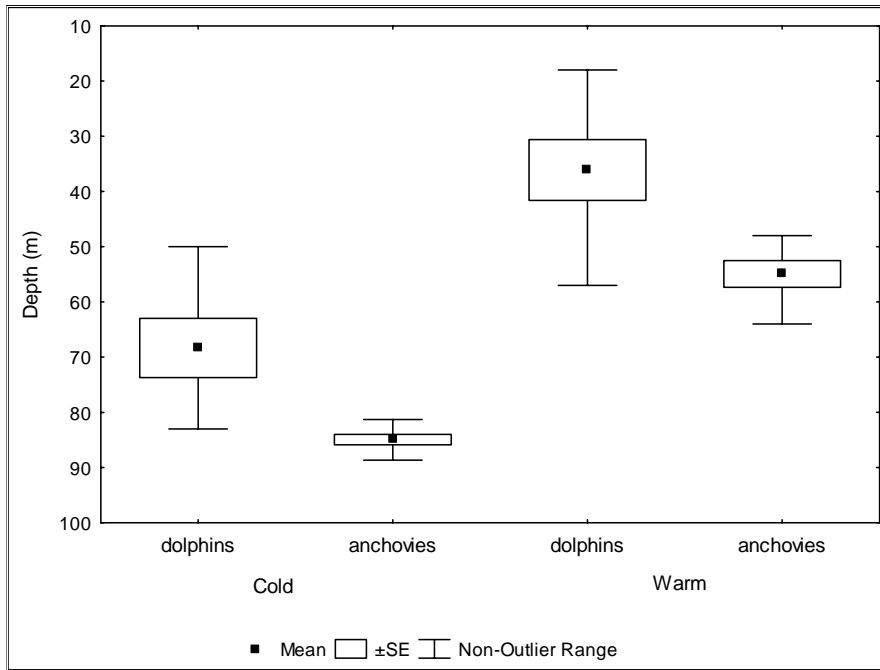


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Figure 4

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Figure 5