

1 Home range and diel behaviour of the ballan wrasse, *Labrus bergylta*,
2 determined by acoustic telemetry

3

4 David Villegas-Ríos^{a,*}, Josep Alós^b, David March^b, Miquel Palmer^b, Gonzalo
5 Mucientes^{a, c}, Fran Saborido-Rey^a

6

7 ^a Instituto de Investigaciones Marinas (IIM-CSIC). 36208. Vigo, Spain

8 ^b Instituto Mediterráneo de Estudios Avanzados (CSIC-UIB). 07190. Esporles,
9 Spain

10 ^c Centro Tecnológico del Mar – Fundación CETMAR. 36208. Vigo, Spain

11

12 * Corresponding author: Tel: +34 986 23 19 30. Fax: +34 986 29 27 62

13

14 E-mail addresses: villegas@iim.csic.es (D. Villegas-Ríos), pep.alos@uib.es (J.
15 Alós), david@imedea.uib-csic.es (D. March), palmer@imedea.uib-csic.es (M.
16 Palmer), gonzalo@iim.csic.es (G. Mucientes), fran@iim.csic.es (F. Saborido-
17 Rey)

18

19 **Running head:** movement patterns of *Labrus bergylta*

20

21 **Abstract**

22 Effective fisheries management needs to consider spatial behaviour in
23 addition to more traditional aspects of population dynamics. Acoustic telemetry
24 has been extensively used to provide information on fish movements over
25 different temporal and spatial scales. Here, we used a fixed-receiver array to
26 examine the movement patterns of *Labrus bergylta* Ascanius 1767, a species
27 highly targeted by the artisanal fleet of Galicia, NW Spain. Data from 25
28 individuals was assessed for a period of 71 days between September and
29 November 2011 in the Galician Atlantic Islands Maritime-Terrestrial National
30 Park. Fish were present within the monitored area more than 92% of the
31 monitored time. The estimated size of individual home ranges, i.e. the area
32 where fish spent most of their time, was small. The total minimum convex
33 polygons area based on all the estimated positions was $0.133 \pm 0.072 \text{ km}^2$,
34 whereas the home range size estimated using a 95% kernel distribution of the
35 estimated positions was $0.091 \pm 0.031 \text{ km}^2$. The core area (50% kernel) was
36 $0.019 \pm 0.006 \text{ km}^2$. *L. bergylta* exhibited different patterns of movement in the
37 day versus the night, with 92% of the fish detected more frequently and
38 travelling longer distances during the daytime. In addition, 76% of the fish
39 displayed a larger home range during the day versus night. The linearity index
40 was less than 0.005 for all fish suggesting random movements but within a
41 relatively small area, and the volume of intersection index between consecutive
42 daily home ranges was 0.75 ± 0.13 , suggesting high site fidelity. The small
43 home range and the sedentary behaviour of *L. bergylta* highlight the potential
44 use of small MPAs as a management tool to ensure a sustainable fishery for
45 this important species.

46 **Keywords:** home range, diel behaviour, site fidelity, marine protected
47 areas, acoustic telemetry, *Labrus bergylta*.

48 **1. Introduction**

49 Fish movement patterns are particularly relevant to marine management
50 and conservation (Alós et al., 2012b). Traditionally, management decisions
51 were based on population-dynamic models that incorporated fishing effort and a
52 number of biological traits. However, they assumed fish populations to be
53 spatially homogeneous (Botsford et al., 2009), even when the biology of the fish
54 and the management tools used had a spatial component (Babcock et al.,
55 2005). As approaches for managing marine resources are improving, there is
56 increasing evidence for the need to integrate spatial information into our
57 understanding of population dynamics (Pecl et al., 2006; Semmens et al.,
58 2010).

59 Understanding fish movement patterns is important, for example, in the
60 design and assessment of marine protected areas (MPAs). MPAs are a
61 multipurpose fishery management tool (Martin et al., 2007), often used to
62 protect a specific life history stage and to promote the healthy populations which
63 will then spillover the boundaries of the MPA to other areas. Thus, the success
64 of MPAs in a fisheries context largely depends on the scale of fish movements
65 in relation to the size of the MPAs. If most of the individuals within the
66 population have home ranges larger than the area of the reserve itself, then the
67 fish will be exposed to fishing pressure and the effectiveness of the reserve will
68 be limited (Kramer and Chapman, 1999). MPAs have been predicted to best
69 serve benthic species with small home ranges and high residency, such as
70 some scarids (e.g. Welsh and Bellwood, 2012), serranids (e.g. Afonso et al.,

71 2011; March et al., 2010) or labroids (e.g. Chateau and Wantiez, 2007; Topping
72 et al., 2005).

73 In spite of its importance, quantifying movement patterns of marine fishes
74 is difficult. Conventional approaches based on external tagging (i.e. mark-
75 recapture studies; Fowler et al., 2002; Palmer et al., 2011) depend in large
76 part on the rate of fish returned by fishermen or anglers. In contrast, acoustic
77 telemetry is able to provide repeated estimates of the position of the same
78 individual and has become a powerful approach that allows tracking of fish over
79 different spatial and temporal scales (Alós et al., 2011; Heupel et al., 2006). In
80 the last years acoustic telemetry has been increasingly used to determine home
81 range size (Collins et al., 2007; Lowe et al., 2003), diel activity pattern (Hitt et
82 al., 2011; Jadot et al., 2006; Meyer et al., 2007), site fidelity (Abecasis and
83 Erzini, 2008; March et al., 2011), and habitat preference (Alós et al., 2011;
84 Topping et al., 2005) of different fish species in a variety of ecoregions.
85 Nonetheless, inference about temporal patterns from telemetry studies should
86 be done with care, and effort must be made in disentangling animal behaviour
87 and rhythms from other factors affecting the probability of detecting a fish (e.g.
88 wind speed, current speeds, biological and environmental noise; Heupel et al.,
89 2006) and the use of fixed control tags has been recently proposed to overcome
90 this problem (Payne et al., 2010).

91 The ballan wrasse, *Labrus bergylta* Ascanius 1767, is one of 13 species
92 of labroids occurring in Galicia, NW Spain (Bañon et al., 2010). It is distributed
93 along the coasts of the north-east Atlantic (from Norway to Morocco) and the
94 Mediterranean, from the shoreline to 60 m depth, and targeted throughout most

95 of this range (Porteiro et al., 1996; Talbot et al., 2012; Treasurer, 1994). In
96 Galicia, it supports an important artisanal gillnet fishery, being one of the three
97 most landed fish species in the last decade (www.pescadegalicia.com; last
98 accessed: 25 Sep 2012), as well as a recreational fishery made up of anglers
99 and spear fishers, who usually select for larger individuals (Lloret et al., 2008).
100 The ballan wrasse is a benthic species, occurring most commonly at depths <
101 30 m (Dipper et al., 1977). It inhabits rocky reefs and kelp beds where it mostly
102 feeds on small invertebrates (Figueiredo et al., 2005). It's long-lived (up to 29
103 yr), with slow growth and a protogynous hermaphrodite without sexual
104 dimorphism in colour (Dipper et al., 1977), which spawns in the spring in
105 northern Europe (Dipper and Pullin, 1979; Muncaster et al., 2010). Management
106 of *L. bergylta* is based solely on a minimum landing size of 20 cm, even though
107 it has been suggested that in sequential hermaphrodites larger individuals
108 should be protected to ensure sex ratios are sufficient for effective mating and
109 fertilization (Alonzo and Mangel, 2004).

110 There is little knowledge of home range size and temporal patterns in
111 movements for this species. However, a pilot study suggested these topics
112 could be successfully addressed with telemetry (Pita and Freire, 2011). In
113 addition, males have been reported to defend small territories (< 300 m²)
114 (Sjolander et al., 1972) and inactivity has been observed at night (Costello,
115 1991, pers. obs.). Thus, *L. bergylta* appears to be a good candidate for spatial
116 management (i.e., MPAs), but the optimal reserve size lacks empirical testing.

117 In this study, we used acoustic telemetry to investigate the individual and
118 temporal variability in the movement patterns of *L. bergylta* over a period of 71

119 days. Specifically, we estimated: (1) residence and site fidelity indexes, (2)
120 temporal patterns and diel behaviour, (3) home range and core area size and
121 (4) fish size related differences in spatio-temporal patterns.

122

123 **2. Material and Methods**

124 This study was conducted at the Cíes Archipelago (Galicia, NW Spain;
125 Fig. 1) between 1 September and 10 November 2011. These islands are part of
126 the Galician Atlantic Islands Maritime-Terrestrial National Park, created in 2002.
127 It comprises an area of ~ 32 km² where limited commercial fishing is allowed
128 with some gear regulations, while recreational fishing is forbidden. The study
129 area is located around a small islet in the channel between two of the main
130 islands (Fig. 1). This is a shallow area with depths between 0 and 23 m
131 encompassing different habitat types, namely rocky reefs, kelp beds, coralline
132 algae and sandy bottoms.

133 *2.1 Receiver array*

134 In September 2010, a preliminary range test was carried out in Ría de
135 Vigo at a location similar to the study area. We specifically tested detection
136 range at 10-15 m depth and over 2 different substrates (soft and hard). We
137 used ©Vemco range test tags V13 and V9 with the same power output as the
138 tags used in this study. A line of 12 receivers was moored covering a distance
139 of 350 m, and both tags were submerged 1 m above the bottom, at the location
140 of the first receiver in the line. The test lasted 112 min, which is the time needed
141 to send out 160 emissions. A generalized linear model (GLM, family

142 quasibinomial) was used for each substrate type to test for differences between
143 proportions of emissions detected at each distance by each tag type. There was
144 no significant difference in the reception range of either tag type with hard ($p =$
145 0.340) or soft ($p = 0.620$) bottom type. Therefore data from both tag types were
146 pooled in subsequent analysis. Maximum detection range was ~ 200 m and
147 ~ 300 m for hard and soft bottoms, respectively, so an intermediate value of 250
148 m was used to design the receivers array.

149 Based on this information a fixed array of 12 acoustic omni-directional
150 receivers ([©]Vemco model VR2W) was deployed at the study site to monitor the
151 spatio-temporal patterns of *L. bergylta* (Fig. 1). Receivers, previously treated
152 with antifouling paint, were attached to the upper end of a metallic auger anchor
153 (140 cm high), which was screwed ~ 60 cm into the substrate. This system
154 allowed good fixation and resistance to bad weather conditions as well as a
155 guaranty of vertical orientation of the receiver. Receivers were placed at depths
156 between 5 and 21 m and the array covered an area of ~ 1.6 km², with a higher
157 density of receivers closer to the place where fish were tagged and released
158 (islet shoreline). The receiver configuration allowed for range overlap and
159 allowed fish to be continuously detected when present inside the monitored
160 area.

161 2.2 Sampling and tagging

162 Sixteen fish were captured at depths < 10 m during daytime with hook
163 and line and the swim bladder punctured quickly for venting the trapped gas.
164 Another 9 fish were captured while resting at night by SCUBA divers at 6-10 m
165 depth and slowly brought to surface (~ 4 m min⁻¹). After acclimatization fish

166 were anesthetized by immersion in a seawater solution of 100 mg l⁻¹ tricaine
167 methanesulfonate (MS-222) for 4.0 ± 1.6 min (mean ± sd; hereafter all values
168 expressed as mean ± sd) until total loss of equilibrium. Individuals were
169 measured to the nearest 0.1 cm and placed in a methacrylate v-shaped “bed”
170 submerged in, a seawater solution of 25 mg l⁻¹ of MS-222. Acoustic tags were
171 implanted into the peritoneal cavity of each fish through a 3 cm longitudinal
172 incision in the abdominal wall and the wound closed with 2-3 sutures. The entire
173 surgical process took less than 4 min. After complete recovery, fish were
174 released in the location of initial capture. Time out of the water was 35 ± 12
175 min. The GPS position, depth, date and hour of release were recorded for each
176 tagged fish.

177 Twenty one fish were tagged with ©Vemco V13-1L-A69-1601 tags (36 x
178 13 mm, 6.0 g in water), with a random delay of 40-80 s, while 4 of the smaller
179 individuals were tagged with V9-2L-A69-1601 (29 x 9 mm, 2.9 g in water) with a
180 random delay of 80-120 s. Battery life in both cases exceeded the duration of
181 the present study. An evaluation of the surgical procedure using dummy
182 transmitters with 8 individuals in captivity revealed normal activity 5-8 min after
183 surgery, normal feeding after 1 day, full cicatrisation without transmitter loss
184 after 3 weeks and 100% survival after 16 months. Fish were tagged before this
185 study (March-April 2011) as part of another experiment, so normal behaviour
186 and complete cicatrisation was assumed. As recommended by Payne et al.
187 (2010) a control tag (V13) was deployed inside the receiver array for the
188 tracking period to assess possible environmental effects on the detection
189 patterns and to have a means to measure fish position error.

190 *2.3 Temporal pattern*

191 Data processing and all analysis were conducted in R (R Development
192 Core Team, 2011). Data were filtered to remove potential spurious detections,
193 defined as any single transmitter code (fish ID) occurring alone at a specific
194 receiver within a 24 h period (Meyer et al., 2007). The total period of detection
195 (TP) for each fish was calculated as the time interval between the first day of
196 the experiment and the last day the fish was detected, while the number of days
197 detected (DD) reflected only those days an individual was detected. Thus, the
198 residence index (RI) for each fish was defined (March et al., 2010) as:

199 $RI = DD / TP$ (1)

200 Detections of all receivers for each fish were pooled into hourly bins (time
201 expressed in UTC). Then, continuous wavelet transforms (CWT) were used to
202 identify periodicity patterns in the time series (Alós et al., 2012a; March et al.,
203 2010). We computed the 2-dimensional wavelet spectrum and calculated a
204 pointwise test at the 95% significance level using a Morlet wavelet with the
205 *sowas* package (Maraun et al., 2007). To investigate diel patterns, the number
206 of detections per hour were pooled and corrected by taking into account the
207 mean hourly detection frequency of the control tag, as described in Payne et al.
208 (2010). This approach quantifies the magnitude of variation of each hourly bin
209 (as standardized detection frequencies, SDFs) around the mean daily detection
210 frequency for the control tag:

$$SDF_b = \frac{B_b}{\mu}$$

211 where μ is the overall mean detection frequency across all hourly bins, b , and B
212 is the mean detection frequency in each hourly bin for the control tag. The mean
213 daily detection frequency for each fish tag was then divided by the
214 corresponding SDF for each bin. Then, the total detections at day and night
215 were pooled and standardized based on the different duration of each phase.
216 Day and night phases were defined using sunrise and sunset data obtained
217 from the U.S. Naval Observatory (<http://aa.usno.navy.mil>; last accessed: 14 Apr
218 2012) for the study area (March et al., 2010; Meyer et al., 2007). A Mann
219 Whitney U-test was used to test for differences in the corrected number of
220 detections between day and night.

221 *2.4 Spatial pattern*

222 We estimated the centres of activity (COA) for each fish at each time bin
223 (Hedger et al., 2008; Simpfendorfer et al., 2008) using the Nadayara-Watson
224 normal kernel estimator with the *sm* package (Bowman and Azzalini, 1997). The
225 resulting set of estimated positions was used as input for the subsequent
226 analysis. Fish position at each time, XY_{ij} , was based on the averaged positions
227 of the receivers that detected fish i during the time bin j and weighted by the
228 number of detections at each receiver over that period. Selection of an
229 appropriate time bin size (Δ_t) is required to get accurate results when using this
230 method and the optimal bin size must balance the need to record sufficient
231 detections from different receivers and the need to not allow the fish to move
232 too much (Simpfendorfer et al., 2002). To select the optimal Δ_t , we calculated
233 the mean number of receivers detecting signals from an individual tag (NR), and
234 then we averaged the number of detections from this tag across all receivers

235 (ND) during each time bin. We tested six different values of Δ_t : 10, 20, 30, 40,
236 50 and 60 min. NR is expected to increase asymptotically as Δ_t increases,
237 whereas ND increases linearly with Δ_t . Better position estimates are obtained
238 when the fish is detected multiple times by multiple receivers (Simpfendorfer et
239 al., 2002). We considered a suitable Δ_t when the increase in NR was $< 10\%$
240 between two consecutive values of Δ_t and ND remained > 10 . The resulting
241 value was $\Delta_t = 30$ min at which NR was 2.8 ± 1.8 receivers for both V13 and V9
242 tags and ND was 10.1 ± 6.9 and 14.4 ± 12.1 detections / time interval for V9
243 and V13 tags, respectively.

244 We used 2 approaches to estimate the home range of each fish over the
245 total period. Minimum convex polygons were estimated based on the full set of
246 fish positions (MCP_{100}). Bivariate normal fixed kernel utilization distributions
247 (KUDs) were estimated based on 95% (home range) and 50% (core area) of
248 the positions (KUD_{95} and KUD_{50} , respectively) using the *adehabitat* package
249 (Calenge, 2006). The MCP_{100} provided information regarding the extent of an
250 animal's range over a given period, while KUDs provided information regarding
251 the use of space within that range including core area and home range. The
252 overlapping area between the small islet located in the receiver array and the
253 activity spaces was subtracted to produce the final results. A kernel bandwidth
254 equal to the error in the estimation of the fish locations was selected (Alós et al.,
255 2012a). As this error is unknown, it was approximated as the mean of the
256 positioning error of the control tag. A linear regression was used to test for
257 differences in the intercept and slope of the home range sizes estimated by
258 MCP_{100} and KUD_{95} .

259 Changes in home range over time were investigated based on KUD₉₅.
260 Observation-area curves were calculated by plotting cumulative home ranges
261 over a period of days. It is expected that as tracking time increases the
262 cumulative KUD₉₅ will initially increase and eventually reach an asymptote,
263 indicating that no additional tracking time is needed to ascertain the true home
264 range of the fish (Rechisky and Wetherbee, 2003). We assumed the asymptote
265 was reached at the time when percent change of the observation-area curve
266 was less than 5% between two consecutive days (Rechisky and Wetherbee,
267 2003). In addition, daily values of KUD₉₅ were estimated for the 71 days and
268 diel (night vs. day) differences in these values were statistically tested using a
269 Wilcoxon signed rank test. For comparison we also estimated the accumulated
270 KUD₉₅ for day and night phases for each fish.

271 The linearity index (L_i) (Alós et al., 2011; Rechisky and Wetherbee, 2003)
272 and the volume of intersection (VI) index (Fieberg and Kochanny, 2005) were
273 calculated for each fish as a proxy for site fidelity. L_i was calculated as:

$$274 \quad L_i = (F_n - F_1) / D \quad (2)$$

275 where $F_n - F_1$ is the distance between the first and last COA, and D is the total
276 distance travelled by the fish. An L_i of 1 indicates linear movements between
277 the first and the last COA and an L_i near 0 indicates little movement from the
278 area and reuse of the same activity space (March et al., 2010). VI index
279 computes the volumetric intersection between two activity spaces and was
280 calculated with the *kerneloverlap* function in the *adehabitat* package (Calenge,
281 2006). The VI index ranges from 0 to 1 (Fieberg and Kochanny, 2005). We
282 estimated 3 VI indices. First, VI index was calculated for daily values of KUD₉₅

283 in order to investigate patterns of space reuse from day to day. A value of 1
284 signifies complete overlap of activity spaces (sedentary behaviour) whereas a
285 value of 0 indicates non-overlap (nomadic behaviour). Second, patterns in
286 home range diel shift were evaluated by estimating the day-night values of VI
287 index for the accumulated KUD_{95} and third, the same was done with the
288 accumulated KUD_{50} . In this case a VI index of 1 indicates complete overlap
289 between day and night activity spaces whereas a VI index of 0 suggests a
290 different use of space during the day and night. Total distance travelled per day
291 (D_t) was approximated by adding up the distances between consecutive COAs
292 for each day. Distance travelled per hour at daytime (D_d) and night time (D_n)
293 were calculated for each day by dividing the distance travelled per diel phase by
294 the duration of the phase, and the differences were tested with a Wilcoxon
295 signed rank test.

296 In addition, linear regression models were used to determine the effects
297 of fish total length (TL) on the home range size (both MCP_{100} and accumulated
298 KUD_{95}) and D_t . The normality of the residuals and model performance were
299 examined by visual inspection of the residual distributions, plotting the residuals
300 against the fitted values and using quantile-quantile (QQ) plots.

301

302 **3. Results**

303 The characteristics of the 25 *L. bergylta* individuals monitored are
304 summarized in Table 1. A total of 822,251 detections were downloaded from the
305 receivers, with a mean of $31,625 \pm 22,366$ detections per fish. On average, an
306 individual fish was detected by 8.2 ± 1.9 receivers over the whole period. Fish

307 were detected by more receivers during daytime (3.8 ± 1.2 receivers per hour)
308 than at night (2.1 ± 0.5 receivers per hour). The mean number of fish detected
309 by a receiver was 17.3 ± 6.0 . The total period of detection was 71 days for all
310 tagged fish with a mean of 70.2 ± 1.4 days detected. The RI varied from 0.92 to
311 1.00 with a mean of 0.99 ± 0.02 .

312 *3.1 Temporal pattern*

313 The corrected number of detections binned by hour and pooled ignoring day
314 (Fig. 2) revealed a clear diel pattern for the majority of fish. The diel pattern was
315 characterized by more detections during the day. Detections from the control
316 tag indicated a significant variability in reception between day and night periods
317 (Fig. 2), with more detections occurring during the night period ($p < 0.05$). The
318 corrected mean number of detections was significantly higher during daytime
319 compared to the night for 24 individuals (Table 2), with the exception of one fish
320 which was more frequently detected at night.

321 The CWT spectrograms (some examples in Fig. 3) detected significant
322 periodicities in the time series of the monitored fish, but not in the control tag.
323 Twenty-four fish presented a clear 24 h periodicity in their spectrograms. In
324 some cases this periodicity extended for the majority of the days ($n = 9$),
325 whereas in others it was more sporadic ($n = 15$). Fish 305 also showed a
326 significant 48 h periodicity in addition to the 24 h periodicity, probably
327 corresponding to the second harmonic of the 24 h period. Fish 285 did not
328 exhibit a 24 h periodicity, but did show a significant 12 h periodicity.

329 *3.2 Spatial patterns*

330 A mean of $2,651 \pm 574$ COAs (fish positions) were estimated for the tagged fish
331 based on 30 min time bins (Table 3). For the control tag, 3,376 COAs were
332 estimated and compared with the true tag position giving a mean estimation
333 error of 45.5 ± 17.0 m.

334 The plots of daily cumulative KUD_{95} (Fig. 4) revealed that although all
335 individuals stabilized their home range area during the study period (mean =
336 16.8 ± 18.6 days), the time needed to achieve it was highly variable, ranging
337 from 1 to 56 days (Fig. 4 and Table 3). Home range (MCP_{100} and KUD_{95}) and
338 core areas (KUD_{50}) are shown in Table 3 while some examples are plotted in
339 Fig. 5. The estimation of home range size obtained with MCP_{100} was $0.133 \pm$
340 0.072 km². MCP_{100} was negatively correlated with fish TL ($\beta = -0.005$, $t = -$
341 2.907 , $p = 0.008$). The estimation of home range size obtained with KUD_{95} was
342 0.091 ± 0.031 km², exhibiting no relationship with fish TL ($p = 0.322$). MCP_{100}
343 estimates were significantly larger than KUD_{95} estimates over the full range of
344 home range sizes, i.e., the linear regression between the home range sizes
345 estimated with MCP_{100} against those estimated with KUD_{95} revealed a slope
346 significantly different from 1 ($\beta = 1.339$, $t = 3.346$, $p = 0.003$) and an intercept of
347 0. The core area based on accumulated KUD_{50} was 0.019 ± 0.006 km² showing
348 no relationship with fish TL ($p = 0.070$).

349 Significant diel differences were found in 22 out of 25 fish in daily KUD_{95}
350 (Table 3), with 19 fish showing significantly larger daily daytime KUD_{95} and 3
351 fish exhibiting larger nighttime KUD_{95} . Fish exhibited the same diel pattern when
352 the accumulated, i.e. asymptotic, KUD_{95} was analyzed with the exception of
353 one. Averaged D_t was 1570 ± 467 m d⁻¹ (Table 4). It was negatively correlated

354 with fish TL ($\beta = -35.06$, $t = -3.107$, $p = 0.005$) and showed a strong positive
355 correlation with KUD_{95} (Pearson $r^2 = 0.82$). D_t varied significantly with the diel
356 phase, with longer distances travelled at day hours in all cases except for one
357 fish (Table 4).

358 L_i and VI indices are shown in table 4. L_i over the full period was $0.0008 \pm$
359 0.0009 . VI index was high based on a KUD_{95} daily shift (0.75 ± 0.13). Day-night
360 VI index ranged between 0.00 and 0.41 in the case of the accumulated KUD_{50}
361 (0.22 ± 0.12) and between 0.18 and 0.86 for the accumulated KUD_{95} ($0.58 \pm$
362 0.17).

363

364 **4. Discussion**

365 *4.1 Residence time and site fidelity*

366 Residence time and site fidelity are important issues to be taken into
367 account when designing MPAs for a given species. High residence time is a
368 typical behaviour among reef associated fishes and has been documented for
369 many different fish families (e.g. Labridae and Serranidae) at different time
370 scales, such as days (23 d for *Xyrichtys novacula*, Alós et al., 2012a), months
371 (up to 27 months for *Semicossyphus pulcher*, Topping et al., 2006) or years (up
372 to 5 years for *Epinephelus marginatus*, Afonso et al., 2011). Our results of RI for
373 *L. bergylta* over the 71 d of study agree with this general pattern of behaviour,
374 with all fish being detected in the monitored area > 92% of the days. Moreover,
375 the fact that all the 25 fish were tagged in the study area months before this
376 study, and were still there in September 2011 when this research started,

377 suggests that the resident behaviour reported might be maintained over longer
378 periods of time. The high residency of *L. bergylta* is supported by the low L_i and
379 high daily VI index values obtained, which reveal a strong sedentary behaviour
380 and non-directional movements.

381 *4.2 Diel behaviour*

382 *L. bergylta* showed a clear diel pattern with a much higher activity during
383 daytime. The 24 h periodicity of this temporal pattern was also clearly observed
384 in the CWT spectrograms for most fish. The interpretation of diel patterns in
385 telemetry studies must, however, be done with care. Environmental conditions
386 (e.g. temperature, salinity, conductivity) may produce spurious periodicities in
387 the detection patterns, even if the animal does not have diel behaviour, which
388 may lead to a misinterpretation of the results (Payne et al., 2010). To assess
389 those effects we used a control tag, which recorded any environment-related
390 temporal pattern and allowed us to remove this from the data prior to assessing
391 movement patterns. Therefore, diel patterns observed were due only to fish
392 behaviour, assuming that there was no spatial variation in environmental
393 artefacts within the monitored area.

394 The existence of a diel pattern is a common characteristic of fish
395 behaviour and has been previously reported for a wide variety of species (Alós
396 et al., 2011; Arendt et al., 2001; Hitt et al., 2011). Some authors found that diel
397 detection patterns were related to actual fish movement in and out of a certain
398 area (Hitt et al., 2011; Topping et al., 2005). A similar pattern could, however,
399 be observed if the animal does not leave the area but displays hiding or burying
400 behaviour at night (March et al., 2010), as has been observed for many labroids

401 (Alós et al., 2012a; Topping et al., 2005). This seems to be the case of *L.*
402 *bergylta* too, which is known to display decreased activity and sheltering
403 behaviour at night hours, when individuals rest inside rock crevices or between
404 the rocks (Costello, 1991; pers. obs.). This behaviour would impede the
405 transmission of the acoustic signals, resulting in the low number of detections
406 observed at night. During the day *L. bergylta* is more mobile and visible
407 (Costello et al., 1993) allowing improved reception of the acoustic signals. This
408 would also increase the potential for signal collisions during the day
409 (Simpfendorfer et al., 2008), which may, at least in part, explain the observed
410 pattern of detection of the control tag (fewer detections during daytime).

411 The temporal diel pattern observed was supported by our spatial results.
412 Estimated home ranges differed between night and day, with most of the fish
413 exhibiting larger daytime home ranges. This result suggests that estimates of
414 home range based solely on data from the daytime, as is common with active
415 tracking studies or direct underwater observations (Barrett, 1995), may not be
416 accurate. Besides, distance travelled at daytime was greater for all but one fish,
417 revealing higher activity during this phase in agreement with the increased
418 diurnal detections. Given that the study period was out of the spawning season
419 of the species, increased daytime movements and activity are presumed to be
420 related to foraging activity. In addition, it is worth mentioning that for the
421 purposes of this research we defined the day and night periods using the
422 sunrise and sunset times, as in other telemetry studies (Alós et al., 2011; Hitt et
423 al., 2011; March et al., 2010). This definition could potentially influence the
424 results of diel behaviour if dawn and dusk movements (included in the night
425 period) were important, resulting in a partially overestimated nocturnal activity.

426 The wide range of values obtained for day-night VI index (for both home
427 range and core area) suggests intra-specific variability in diel patterns in the use
428 of space. Some fish used relatively different areas for night and day activities
429 (e.g. resting vs. foraging), while others remained in the same space throughout,
430 similar to other temperate and tropical reef associated species (Lowe et al.,
431 2003; Marshall et al., 2011; Meyer and Holland, 2005).

432 4.3 Home range size

433 The small home range obtained for *L. bergylta* ($KUD_{95} = 0.091 \text{ km}^2$) is in
434 agreement with a sedentary behaviour previously reported for this species
435 (Costello, 1991; Sjolander et al., 1972). Reported territory size for males during
436 spawning was $< 300 \text{ m}^2$ (0.0003 km^2 ; Sjolander et al., 1972), much smaller than
437 our estimations of home range size. Due to the nest guarding behaviour of the
438 species (pers. obs), the estimation by Sjolander et al., (1972) likely corresponds
439 to the range of movement of the guarding males during the day (when
440 observations were made), rather than the true home range of the species.

441 Home range size estimations are determined by the temporal scale at
442 which they are calculated. Measurements along several consecutive days are
443 required to obtain an asymptotic, i.e. accumulated value, to be used as an index
444 of home range (March et al., 2010). Therefore, not taking into account the
445 temporal scale, i.e. measuring home range over short periods, can lead to
446 biased results and erroneous conclusions. In the case of *L. bergylta* all the
447 individuals stabilized their home range during the study period showing that no
448 additional tracking time was needed for a reliable estimation of the home range
449 size. Pita & Freire (2011) estimated a home range size of 0.003 km^2 and 0.005

450 km² for two individuals of *L. bergylta* that were manually tracked for 1 and 4
451 days, respectively, which might lead to underestimated results. The home range
452 size reported in the present study for *L. bergylta* is in the range of other
453 hermaphroditic labroids with complex social structures like *Xyrichtys novacula*
454 (0.32 km²; Alós et al., 2012a), *Coris julis* (0.13 km²; Palmer et al., 2011) or
455 *Semicossyphus pulcher* (0.02 km²; Topping et al., 2005).

456 Intra-specific variability in home range sizes may be influenced by many
457 biological or environmental factors (Quinn and Brodeur, 1991). Different
458 relationships have been found between fish TL and home range size for
459 sedentary species, from positive (Jones, 2005) to negative (Kaunda-Arara and
460 Rose, 2004; Meyer and Holland, 2005), or no relationship (Alós et al., 2011;
461 March et al., 2010). Additionally, the estimation of the home range size is highly
462 dependent on the method used (Walter et al., 2011), which was supported by
463 our results. Home range size of *L. bergylta* based on MCP₁₀₀ was negatively
464 correlated with fish TL, although KUD₉₅ was not correlated at all. The strong
465 correlation between KUD₉₅ and D_t further supports the idea that home range
466 size is correlated with fish TL. Smaller fish travelled longer distances, resulting
467 in larger home ranges, as evidenced by the negative relationship between fish
468 TL and D_t. Higher mobility and larger home range (based on MCP₁₀₀) in smaller
469 individuals of *L. bergylta* may indicate that they are too small to effectively
470 defend a territory, in contrast with adult territorial individuals that can satisfy
471 their energetic demands within a small area in high quality habitats (Grüss et
472 al., 2011). In addition, KUD estimates are influenced by the selection of the
473 bandwidth. Smaller values are preferred with large sample sizes as they
474 produce less biased results (Kie et al., 2010). In this study, we used the mean

475 of the positioning error of the control tag which allowed us to incorporate the
476 uncertainty of positional errors into the home range estimates (Alós et al.,
477 2012a) while increasing the spatial resolution.

478 *4.4 Implications for fishery management*

479 Results from this research have direct implications for conservation and
480 should be integrated into the management of *L. bergylta*. At present, this
481 species is managed solely on a minimum landing size of 20 cm, an inadequate
482 measure for protogynous species as the larger males may then have
483 inadequate protection (Alonzo and Mangel, 2004). We have demonstrated that
484 *L. bergylta* exhibits a high site fidelity and a limited home range that together
485 with the reported slow growth rate (Dipper et al., 1977) and their hermaphroditic
486 reproductive strategy makes this species particularly vulnerable to overfishing
487 (Sattar et al., 2008). Those fisheries which target larger individuals such as
488 angling and recreational spear fishing may especially impact resident
489 populations.

490 In the present study, clear diel behaviour was observed with increased
491 distance travelled during day hours. The probability of catching a fish in a gillnet
492 is directly proportional to the probability of the fish encountering the net and
493 being trapped in it, which in turn depends on the distance travelled by the fish
494 (Rudstam et al., 1984). Thus, a higher catch rate is expected for *L. bergylta*
495 during the daytime. Moreover, the negative relationship between fish TL and
496 distance travelled (a proxy of activity) suggest a complex catchability pattern:
497 small fish will be more prone to be caught because they move more actively but
498 only when they reach the size threshold of the gear.

499 A consequence of the sedentary behaviour of the species and the small
500 home range is that relatively small MPAs may effectively protect this species
501 (Barrett, 1995). Effective protection of *L. bergylta* by small MPAs could
502 augment the number and size of the individuals inside it (reserve effect),
503 increasing the reproductive potential of the population due to the allometric
504 increase in fecundity with size of most fish (Alonso-Fernández et al., 2008;
505 Birkeland and Dayton, 2005). Maintaining an intact population structure inside
506 the MPA would also prevent sperm limitation (Alonzo and Mangel, 2004) and
507 thus favour fertilization rates. The protected population would function as a
508 source of larvae to adjacent harvested areas, maintaining sustainable
509 population levels. Furthermore, if the population biomass within MPAs
510 increases, density-dependent factors may force small and intermediate-sized
511 fish to migrate and relocate their home range outside the MPA (Grüss et al.,
512 2011; Kramer and Chapman, 1999; Lowe et al., 2003) thus being accessible to
513 the fishery. All this information should be taken into consideration by managers
514 designing small MPAs, at a point when their use is starting to be considered as
515 an effective management tool in NW Spain.

516

517 **Acknowledgments**

518 We would like to thank all the people from the Fisheries Ecology Group
519 (IIM-CSIC) who helped with the logistic of this research. We are also grateful to
520 the Grupo de Recursos Marinos y Pesquerías (Universidade da Coruña) for
521 lending us part of the telemetry equipment. Special thanks to Dr. F. Pinto and
522 two anonymous reviewers for their suggestions to improve the manuscript. We
523 are deeply indebted to J. Irisarri for his precious help in the study area selection,

524 boat availability and tagging procedures, and to the Parque Nacional Marítimo
525 Terrestre de las Islas Atlánticas for permissions and logistic help. This study
526 was supported by the research project ARTEVIGO funded by Xunta de Galicia
527 (09MMA022402PR) which had no involvement in the study design or data
528 analysis and interpretation. D. Villegas-Ríos was partially financed by a FPU
529 Scholarship from the Spanish Minister of Economy and Competitiveness. This
530 paper is dedicated to Nico.

531

532 **References**

533

534 Abecasis, D., Erzini, K., 2008. Site fidelity and movements of gilthead sea
535 bream (*Sparus aurata*) in a coastal lagoon (Ria Formosa, Portugal). Est Coast
536 Shelf Sci 79, 758-763.

537 Afonso, P., Fontes, J., Santos, R.S., 2011. Small marine reserves can offer long
538 term protection to an endangered fish. Biol Conserv 144, 2739-2744.

539 Alonso-Fernández, A., Domínguez-Petit, R., Bao, M., Rivas, C., Saborido-Rey,
540 F., 2008. Spawning pattern and reproductive strategy of female pouting
541 *Trisopterus luscus* (Gadidae) on the Galician shelf of north-western Spain.
542 Aquat Living Resour 21, 383-393.

543 Alonzo, S.H., Mangel, M., 2004. The effects of size-selective fisheries on the
544 stock dynamics of and sperm limitation in sex-changing fish. Fish Bull 102, 1-
545 13.

546 Alós, J., Cabanellas-Reboredo, M., Lowerre-Barbieri, S., 2012a. Diel behaviour
547 and habitat utilisation by the pearly razorfish during the spawning season. Mar
548 Ecol Prog Ser 460, 207-220.

549 Alós, J., March, D., Palmer, M., Grau, A., Morales-Nin, B., 2011. Spatial and
550 temporal patterns in *Serranus cabrilla* habitat use in the NW Mediterranean
551 revealed by acoustic telemetry. Mar Ecol Prog Ser 427, 173-186.

552 Alós, J., Palmer, M., Arlinghaus, R., 2012b. Consistent Selection towards Low
553 Activity Phenotypes When Catchability Depends on Encounters among Human
554 Predators and Fish. PLoS ONE 7, e48030.

555 Arendt, M.D., Lucy, J.A., Evans, D.A., 2001. Diel and seasonal activity patterns
556 of adult tautog, *Tautoga onitis*, in lower Chesapeake Bay, inferred from
557 ultrasonic telemetry. *Environ Biol Fish* 62, 379-391.

558 Babcock, E.A., Pikitch, E.K., McAllister, M.K., Apostolaki, P., Santora, C., 2005.
559 A perspective on the use of spatialized indicators for ecosystem-based fishery
560 management through spatial zoning. *ICES J Mar Sci* 62, 469-476.

561 Bañon, R., Villegas-Ríos, D., Serrano, A., Mucientes, G., Arronte, J., 2010.
562 Marine fishes from Galicia (NW Spain): an updated checklist. *Zootaxa* 2667.

563 Barrett, N., 1995. Short- and long-term movement patterns of six temperate reef
564 fishes (Families Labridae and Monacanthidae). *Mar Freshw Res* 46, 853-860.

565 Birkeland, C., Dayton, P.K., 2005. The importance in fishery management of
566 leaving the big ones. *Trends Ecol Evol* 20, 356-358.

567 Botsford, L.W., Brumbaugh, D.R., Grimes, C., Kellner, J.B., Largier, J.,
568 O'Farrell, M.R., Ralston, S., Soulanille, E., Wespestad, V., 2009. Connectivity,
569 sustainability, and yield: Bridging the gap between conventional fisheries
570 management and marine protected areas. *Rev Fish Biol Fish* 19, 69-95.

571 Bowman, A., Azzalini, A., 1997. Applied smoothing techniques for data analysis:
572 the kernel approach with S-Plus illustrations, Oxford.

573 Calenge, C., 2006. The package "adehabitat" for the R software: A tool for the
574 analysis of space and habitat use by animals. *Ecol Model* 197, 516-519.

575 Chateau, O., Wantiez, L., 2007. Site fidelity and activity patterns of a humphead
576 wrasse, *Cheilinus undulatus* (Labridae), as determined by acoustic telemetry.
577 *Environ Biol Fish* 80, 503-508.

578 Collins, A.B., Heupel, M.R., Motta, P.J., 2007. Residence and movement
579 patterns of cownose rays *Rhinoptera bonasus* within a south-west Florida
580 estuary. *J Fish Biol* 71, 1159-1178.

581 Costello, M.J., 1991. Review of the biology of wrasse (Labridae:Pisces) in
582 Northern Europe. *Prog Underw Sci* 16, 29-51.

583 Costello, M.J., Darwall, W.R., Lysaght, S., 1993. Activity patterns of north
584 European wrasse (Pisces, Labridae) species and precision of diver survey
585 techniques, in: Eleftheriou, A., Ansel, A.D., Smith, C.J. (Eds.), 28 European
586 Marine Biology Symposium, Crete.

587 Dipper, F.A., Bridges, C.R., Menz, A., 1977. Age, growth and feeding in the
588 ballan wrasse *Labrus bergylta* Ascanius 1767. *J Fish Biol* 11, 105-120.

589 Dipper, F.A., Pullin, R.S.V., 1979. Gonochorism and sex-inversion in British
590 Labridae (Pisces). *J Zool* 187, 97-112.

591 Fieberg, J., Kochanny, C.O., 2005. Quantifying home-range overlap: the
592 importance of the utilization distribution. *J Wildl Manage* 69, 1346-1359.

593 Figueiredo, M., Morato, T., Barreiros, J.P., Afonso, P., Santos, R.S., 2005.
594 Feeding ecology of the white seabream, *Diplodus sargus*, and the ballan
595 wrasse, *Labrus bergylta*, in the Azores. *Fish Res* 75, 107-119.

596 Fowler, A.J., Jones, G.K., McGarvey, R., 2002. Characteristics and
597 consequences of movement patterns of King George whiting (Perciformes:
598 *Sillaginodes punctata*) in South Australia. *Mar Freshw Res* 53, 1055-1069.

599 Grüss, A., Kaplan, D.M., Guénette, S., Roberts, C.M., Botsford, L.W., 2011.
600 Consequences of adult and juvenile movement for marine protected areas. *Biol*
601 *Conserv* 144, 692-702.

602 Hedger, R.D., Martin, F., Dodson, J.J., Hatin, D., Caron, F., Whoriskey, F.G.,
603 2008. The optimized interpolation of fish positions and speeds in an array of
604 fixed acoustic receivers. ICES J. Mar. Sci. 65, 1248-1259.

605 Heupel, M.R., Semmens, J.M., Hobday, A.J., 2006. Automated acoustic
606 tracking of aquatic animals: scales, design and deployment of listening station
607 arrays. Mar Freshw Res 57, 1-13.

608 Hitt, S., Pittman, S., Nemeth, R., 2011. Diel movements of fishes linked to
609 benthic seascape structure in a Caribbean coral reef ecosystem. Mar Ecol Prog
610 Ser 427, 275-291.

611 Jadot, C., Donnay, A., Acolas, M.L., Cornet, Y., Begout Anras, M.L., 2006.
612 Activity patterns, home-range size, and habitat utilization of *Sarpa salpa*
613 (Teleostei: Sparidae) in the Mediterranean Sea. ICES J. Mar. Sci. 63, 128-139.

614 Jones, K.M.M., 2005. Home range areas and activity centres in six species of
615 Caribbean wrasses (Labridae). J Fish Biol 66, 150-166.

616 Kaunda-Arara, B., Rose, G.A., 2004. Homing and site fidelity in the greasy
617 grouper *Epinephelus tauvina* (Serranidae) within a marine protected area in
618 coastal Kenya. Mar Ecol Prog Ser 277, 245-251.

619 Kie, J.G., Matthiopoulos, J., Fieberg, J., Powell, R.A., Cagnacci, F., Mitchell,
620 M.S., Gaillard, J.-M., Moorcroft, P.R., 2010. The home-range concept: are
621 traditional estimators still relevant with modern telemetry technology? Proc R
622 Soc Lond B 365, 2221-2231.

623 Kramer, D.L., Chapman, M.R., 1999. Implications of fish home range size and
624 relocation for marine reserve function. Environ Biol Fish 55, 65-79.

625 Lloret, J., Zaragoza, N., Caballero, D., Font, T., Casadevall, M., Riera, V., 2008.
626 Spearfishing pressure on fish communities in rocky coastal habitats in a
627 Mediterranean marine protected area. *Fish Res* 94, 84-91.

628 Lowe, C.G., Topping, D.T., Cartamil, D.P., Papastamatiou, Y.P., 2003.
629 Movement patterns, home range, and habitat utilization of adult kelp bass
630 *Paralabrax clathratus* in a temperate no-take marine reserve. *Mar Ecol Prog Ser*
631 256, 205-216.

632 Maraun, D., Kurths, J., Holschneider, M., 2007. Nonstationary Gaussian
633 processes in wavelet domain: Synthesis, estimation, and significance testing.
634 *Phys Rev E* 75, 016707.

635 March, D., Alós, J., Grau, A., Palmer, M., 2011. Short-term residence and
636 movement patterns of the annular seabream *Diplodus annularis* in a temperate
637 marine reserve. *Est Coast Shelf Sci* 92, 581-587.

638 March, D., Palmer, M., Alós, J., Grau, A., Cardona, F., 2010. Short-term
639 residence, home range size and diel patterns of the painted comber *Serranus*
640 *scriba* in a temperate marine reserve. *Mar Ecol Prog Ser* 400, 195-206.

641 Marshall, A., Mills, J., Rhodes, K., McIlwain, J., 2011. Passive acoustic
642 telemetry reveals highly variable home range and movement patterns among
643 unicornfish within a marine reserve. *Coral Reefs* 30, 631-642.

644 Martin, K., Samoilyš, M.A., Hurd, A.K., Meliane, I., Gustaf Lundin, C.G., 2007.
645 Experiences in the use of marine protected areas with fisheries management
646 objectives-a review of case studies. Report and documentation of the expert
647 workshop on marine protected areas and fisheries management: review of
648 issues and considerations, in: Report, F.F. (Ed.), Report and documentation of
649 the expert workshop on marine protected areas and fisheries management:

650 review of issues and considerations. FAO Fisheries Report, Rome 12-14 June
651 2006, 825: 21-109, pp. 21-109.

652 Meyer, C.G., Holland, K.N., 2005. Movement patterns, home range size and
653 habitat utilization of the bluespine unicornfish, *Naso unicornis* (Acanthuridae) in
654 a Hawaiian marine reserve. Environ Biol Fish 73, 201-210.

655 Meyer, C.G., Holland, K.N., Papastamatiou, Y.P., 2007. Seasonal and diel
656 movements of giant trevally *Caranx ignobilis* at remote Hawaiian atolls:
657 implications for the design of marine protected areas. Mar Ecol Prog Ser 333,
658 13-25.

659 Muncaster, S., Andersson, E., Kjesbu, O.S., Taranger, G.L., Skiftesvik, A.B.,
660 Norberg, B., 2010. The reproductive cycle of female Ballan wrasse *Labrus*
661 *bergylta* in high latitude, temperate waters. J Fish Biol 77, 494-511.

662 Palmer, M., Balle, S., March, D., Alós, J., M, L., 2011. Size estimation of circular
663 home range from fish mark-release-(single)-recapture data: case study of a
664 small labrid targeted by recreational fishing. Mar Ecol Prog Ser 430, 87-97.

665 Payne, N., Gillanders, B., Webber, D., Semmens, J., 2010. Interpreting diel
666 activity patterns from acoustic telemetry: the need for controls. Mar Ecol Prog
667 Ser 419, 295-301.

668 Pecl, G.T., Tracey, S.R., Semmens, J.M., Jackson, G.D., 2006. Use of acoustic
669 telemetry for spatial management of southern calamary *Sepioteuthis australis*, a
670 highly mobile inshore squid species. Mar Ecol Prog Ser 328, 1-15.

671 Pita, P., Freire, J., 2011. Movements of three large coastal predatory fishes in
672 the northeast Atlantic: a preliminary telemetry study. Sci Mar 75, 759-770.

673 Porteiro, F., Barreiros, J.P., Santos, R.S., 1996. Wrasses (Teleostei: Labridae)
674 of the Azores. Archipelago: Life and Marine Sciences 14A, 23-40.

675 Quinn, T.P., Brodeur, R.D., 1991. Intra-specific Variations in the Movement
676 Patterns of Marine Animals. *Am Zool* 31, 231-241.

677 Rechisky, E.L., Wetherbee, B.M., 2003. Short-term Movements of Juvenile and
678 Neonate Sandbar Sharks, *Carcharhinus plumbeus*, on their Nursery Grounds in
679 Delaware Bay. *Environ Biol Fish* 68, 113-128.

680 Rudstam, L.G., Magnuson, J.J., Tonn, W.M., 1984. Size selectivity of passive
681 fishing gear: a correction for encounter probability applied to gill nets. *Can J*
682 *Fish Aquat Sci* 41, 1252-1255.

683 Sattar, S.A., rgensen, C., Fiksen, yvind, 2008. Fisheries-Induced Evolution of
684 Energy and Sex Allocation. *Bull Mar Sci* 83, 235-250.

685 Semmens, J.M., Buxton, C.D., Forbes, E., Phelan, M.J., 2010. Spatial and
686 temporal use of spawning aggregation sites by the tropical sciaenid *Protonibea*
687 *diacanthus*. *Mar Ecol Prog Ser* 403, 193-203.

688 Simpfendorfer, C.A., Heupel, M.R., Collins, A.B., 2008. Variation in the
689 performance of acoustic receivers and its implication for positioning algorithms
690 in a riverine setting. *Can J Fish Aquat Sci* 65, 482-492.

691 Simpfendorfer, C.A., Heupel, M.R., Hueter, R.E., 2002. Estimation of short-term
692 centers of activity from an array of omnidirectional hydrophones and its use in
693 studying animal movements. *Can J Fish Aquat Sci* 59, 23-32.

694 Sjolander, S., Larson, H., Engstrom, J., 1972. On the reproductive behaviour of
695 two labrid fishes, the ballan wrasse (*Labrus bergylta*) and Jago's goldsinny
696 (*Ctenolabrus rupestris*). *Rev Comp Anim* 6, 43-51.

697 Talbot, C., Medeiros, M.V., Davie, A., 2012. In vivo gender determination in
698 captive ballan wrasse (*Labrus bergylta* Ascanius 1767). Final Report to the
699 Scottish Salmon Producers Organisation 54.

700 Topping, D.T., Lowe, C.G., Caselle, J.E., 2005. Home range and habitat
701 utilization of adult California sheephead, *Semicossyphus pulcher* (Labridae), in
702 a temperate no-take marine reserve. *Mar Biol* 147, 301-311.

703 Topping, D.T., Lowe, C.G., Caselle, J.E., 2006. Site fidelity and seasonal
704 movement patterns of adult California sheephead *Semicossyphus pulcher*
705 (Labridae): an acoustic monitoring study. *Mar Ecol Prog Ser* 326, 257-267.

706 Treasurer, J.W., 1994. The distribution, age and growth of wrasse (Labridae) in
707 inshore waters of west Scotland. *J Fish Biol* 44, 905-918.

708 Walter, W.D., Fischer, J.W., Baruch-Mordo, S., VerCauteren, K.C., 2011. What
709 Is the Proper Method to Delineate Home Range of an Animal Using Today's
710 Advanced GPS Telemetry Systems: The Initial Step, in: Krejcar, O. (Ed.),
711 Modern Telemetry. InTech, p. 470.

712 Welsh, J., Bellwood, D., 2012. Spatial ecology of the steephead parrotfish
713 (*Chlorurus microrhinos*): an evaluation using acoustic telemetry. *Coral Reefs*
714 31, 55-65.

715

716

717

718 **Figure captions**

719 Figure 1 Map of the study site showing the location of the 12 acoustic receivers
720 and the extension of the monitored area

721 Figure 2 Plot of mean detections and standard deviation for the control tag (a)
722 and mean corrected detections per hour (UTC) for each tagged *Labrus bergylta*
723 (b, c, d, e and f). Vertical lines represent sunrise and sunset. Diel phase is
724 indicated as “n” (night) or “d” (day). Note the difference in Y-axis scale

725 Figure 3 Wavelet sample spectrums fitted for individuals 283, 285, 288, 291,
726 292, 296, 299, 304, 305 and the control tag. Individuals were selected to
727 represent the different periodicity patterns obtained, covering the full range of
728 fish sizes. Continuous lines represent the cone of influence (COI). Values
729 outside de COIs should not be interpreted due to edge effects. Thick contours
730 represent the 95% confidence level

731 Figure 4 Daily cumulative home ranges based on KUD_{95} for all the tagged
732 *Labrus bergylta*. Days needed to reach the asymptote are indicated in the
733 legend. Information is presented in four different plots to improve visualization.
734 Note the different Y-axis scales

735 Figure 5 Plots of total, night and day space utilization estimated for fish 283,
736 288, 289, 293, 302, 304, 306 and 429. Individuals were selected to represent
737 the full range of home range sizes and IOR values. Fixed acoustic receivers are
738 shown as black points, and location of capture and release for each fish as a
739 red dot. MCP = minimum convex polygons based on 100% of the positions;
740 KUD_{95} = kernel utilization distribution based on 95% of the positions; KUD_{50} =
741 kernel utilization distribution based on 50% of the positions

