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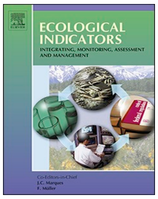

The use of 3-axial accelerometers to evaluate sound production in European spiny lobster, *Palinurus elephas*

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ABSTRACT

The European spiny lobster *Palinurus elephas* emits sound (“rasp”), moving the base of their antennas, as response to the presence of predator and for interspecific communication. During the last decade, three-axial accelerometers have been used to mainly describe diel activity patterns, circadian rhythms and rate of energy consumption of different lobster species, but these devices can also record sound emission in terms of mechanical vibration of carapace. In order to evaluate the efficiency of accelerometers in recording sound production (rasp events and number of pulses inside each rasp) and in discriminating of that from other behavioural events, accelerometers were used in combination with hydrophone and during mesocosm free ranging conditions. Three-axial accelerometers were able to detect sound production events in *P. elephas*. All the rasp events ($n = 405$) recorded with hydrophones were also detected by the accelerometers considering its data sampled at different frequency (from 800 Hz to 12 Hz). However, the detection of the number of pulses within each rasp sound decreased with sampling frequency of accelerometer data (median of predictive error for 800 Hz = 0.33; median of predictive error for 12 Hz = 0.65). During mesocosm free condition, three behavioural categories were identified: walk, tail flip, and rasp, the last with averaged ($15.16 \pm 3.52\,\mathrm{m/s^2}$) and maximum ($29.49 \pm 9.37\,\mathrm{m/s^2}$) values of acceleration significantly higher than the other two. Findings from this study prove that accelerometers register only lobster body vibrations providing a clear signal that is not distorted by other noises in the environment. They also allowed to identify rasps for each tagged lobster, something not possible using hydrophones in both, aquaria or natural habitat. Accelerometer resulted an useful tool to detect behaviours even with low mobility species. Moreover, the possibility to couple accelerometer and other biologging techniques would help to improve our understanding of the behaviour of a large range of free-living species.

1. Introduction

Accelerometers are electromechanical devices designed to measure acceleration forces caused by gravity and moving or vibrating activity of a subject. These sensors, calibrated with a proxy for energy consumption (e.g. heart beats), can also provide estimates of activity-related energy expenditure of an organism (Mori et al., 2015; Wright et al., 2014; Wilson et al., 2006). In particular, three-axial accelerometers are able to measure the vibration, motion, displacement of an organism in X, Y, Z direction. For these reasons, in the last 20 years three-axial accelerometers have been used to study and monitor animal behaviour and bioenergetics at a high recording rate. This technology has been successfully applied in combination with other sensors (pressure, gps, magnetometer, heart rate or ultrasonic tags), to offer insights into the ecology, physiology, and behaviour of different species (Crossin et al., 2014). Moreover, the high correlation between accelerometer data and movement of free-living individuals in different behavioural contexts (e.g. feeding, escaping, swimming/walking), could be used to classify different behavioural states. Indeed, accelerometers allow to know detailed ethograms and behavioural patterns of animals in terms of time spent for their daily activities or to describe their movements in relation to environmental changes (temperature, currents, daylight phases) (Gleiss et al., 2017; Van Deurs et al., 2017; Landsman et al., 2015, Beltramino et al., 2018).

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Accelerometers have been successfully applied to several marine organisms (Ciancio et al., 2016; Broell et al., 2016) and they are considered useful devices for monitoring the activity of a variety of lobster species. Goldstein et al. (2015) described different traits such as diel activity patterns and circadian rhythms of the Mediterranean Slipper lobsters (*Scyllarides latus*,). Lyons et al. (2013) used accelerometers to estimate rate of energy consumption in American lobster (*Homarus americanus*) while Henninger and Watson, 2005 assessed the sound emission in American lobsters by characterizing the mechanical vibration of its carapace. However, today, very few studies deal with lobsters and to our knowledge no one deals with the European spiny lobster.

Palinurus elephas (Hunter, 1999) inhabits the north-eastern Atlantic and the Mediterranean from a few meters down to about 200 m depth, more commonly between 10 and 70 m (Holthuis, 1991). In Mediterranean, *P. elephas* is subject to intense fishing due to its high commercial value (Ceccaldi and Latrouite, 2001; Goñi and Latrouite, 2005) and for this reason it is a vulnerable species of the IUCN red list. The European spiny lobster is a sedentary crustacean species which spends daytime hours mainly on rocky coralligenous substrata rich in crevices and holes and walk at night in search of food at a maximum speed of 255 m/h (Giacalone et al., 2015). Like other crustacean (Buscaino et al., 2012; Favaro et al., 2011; Fornshell et al., 2010; Patek and Oakley, 2003), this species is able to produce sounds, a sort of stridulation, technically termed “rasp” composed by many “impulses” (Patek and Oakley, 2003). A “rasp” is the mechanism underlying the sound production in this crustacean species, it is a stick–slip friction between two structures (plectrum and file) at the base of the antennas (Buscaino et al., 2011a; Patek and Baio, 2007; Patek, 2002). This friction sounds like a palm mute guitar and results in a vibration of the whole animal cephalotorax. The ecological context of lobsters’ sound emission is proven to be mainly related to anti-predatory behaviour, as lobsters increase the events of sound production when a predator is attacking (Buscaino et al., 2011b, Ward et al., 2011). Indeed, when threatened by a predator, spiny lobster starts to emit sounds by moving the antennas, pointing them towards the predator, until, in case of attack, the animal moves backwards by contracting quickly the abdomen muscolature (tail flip) (Buscaino et al., 2011b). Like other crustaceans, *P. elephas* emits sound in presence of predator, even if an intraspecific communication role of the stridulation is not completely excluded (Buscaino et al., 2011a). All these aspects were investigated by mean of acoustical devices. Observing, recording and analysing those data for a single lobster it was possible only in a controlled environment. In the sea, where all of the sources of acoustic signals cannot be known (Ceraulo et al., 2018), these ultrasound pulses could not be attributed to a single *P. elephas*. Accelerometers could overcome this technical limitation, considering that the device will record only acceleration in the three axes produced by movement of a single animal, the one who carries the device.

The goals of this study are: (i) to verify whether or not the 3-axial accelerometer is able to detect the mechanical vibrations of European spiny lobster carapace during sound production and, (ii) characterize the frequency ranges at which the 3-axial accelerometer is able to detect a sound production event (rasp) and/or to detect impulse events within a rasp. In order to achieve these objectives, part of the study was carried out during a controlled sound production condition experiment where acceleration and acoustic data were synchronically collected. A third objective is (iii) to evaluate if the signal recorded by the accelerometers during acoustic production is distinguishable from other signals recorded during other behavioural contexts. For this reason, an experiment was conducted in a mesocosm with free-ranging tagged animals.

2. Materials & methods

2.1. Lobster housing and equipment used

For our experiments, we used 20 wild lobsters caught by local fisherman along the north western coast of Sicily, Italy. Lobsters were transferred to the facilities of CNR-IAS in Capo Granitola (Campobello di Mazara, Italy) into a 4000 l circular PVC “storage” tank equipped with an independent flow-through seawater system from a common source (seawater well). Salinity and water temperature (daily measured) were 32.4 ± 1.2‰ and 18 ± 0.9 °C respectively. The tank was placed in an open space covered by a roof of plastic windbreak mesh in order to avoid any direct insolation and preserve the 14l:10D natural light cycle (July 2016). At the starting of the experiments all lobsters were in perfect health conditions (e.g. all legs, entire antennas, no stereotypy, no abnormal mobility) and their mean ± sd carapace length (CL) was 82.1 ± 5.4 mm.

The devices, X16-mini (Gulf Coast Data Concepts Company) triaxial accelerometers, were set at a recording frequency of 800 Hz and 50 Hz for acoustic and mesocosm trials respectively, and then they were encapsulated with heat-shrinking tube following the protocol described in Ciancio et al. (2016). The sealed accelerometers were attached to the lobster carapaces using quick hardening 1-minute epoxide glue after drying the gluing area with an aquarium air pump to ensure proper adhesion. After experimental tests, the accelerometers were detached from lobsters’ carapace and the acceleration data for each animal were downloaded.

The acoustic data were collected by means of a calibrated hydrophone (model Reson TC4034-3, linear frequency range from 1 to 250 kHz, sensitivity of −218 (+2, −4 dB) dB re 1 V/ μPa connected with a digital acquisition card (USGH416HB, Avisoft Bioacoustics, septate with 40 dB gain) managed by a dedicated Avisoft Recorder USGH software (Avisoft Bioacoustics). Acoustic data were collected using a sample frequency of 300 kHz at 16 bit. Two GOPRO cameras recorded video and audio clips of lobsters during the experiments.

2.2. Controlled sound production condition

2.2.1. Experimental set-up

After a week of acclimation in the storage tank, eight lobsters (CL of 83.0 ± 6.1 mm, 4 males and 4 females) were individually tagged with accelerometers (frequency 800 Hz) and one individual per trial was transferred into a 500 l PVC experimental tank. Once in the tank, an operator holds the tagged lobster abdomen and tail against the tank floor, in order to avoid any confusing factor due to possible tail flips or extra noises within the tank (for example lobster body hitting the tank walls). Antennas and cephalotorax were left free to move or vibrate during sound emission, legs were also free to move, but no movements were recorded during the trial. An *Octopus vulgaris* inside a net box was introduced into the experimental tank to stimulate lobster in emitting sound by antennas. Each trial was interrupted when, at least, 20 acoustic events were recorded.

2.2.2. Accelerometer and acoustic analysis

The acceleration raw data collected for each lobster were converted to m/s^2 data following the accelerometer producer conversion constant (Gulf Coast Data Concepts, 2014). Using a Matlab custom script, the 3-dimension acceleration data (A_x, A_y, A_z) were oversampled from 800 Hz to 300 kHz in order to let them temporally comparable to the acoustic wav data in Relative Volt (*RelV*). Considering the contemporary time interval of acoustic and acceleration recordings, data were synchronized using the first intensity peak of both data.

From oversampled 3-axis acceleration data, we obtained a scalar value following the formula:

$$A^2 = (A_x^2 + A_y^2 + A_z^2)$$

A 300 kHz 2-ch acceleration-acoustic file was written, reporting in the first channel, the normalized squared acceleration scalar value and in the second channel, the normalized squared acoustic data. In both channels the normalization was carried out dividing the single value by

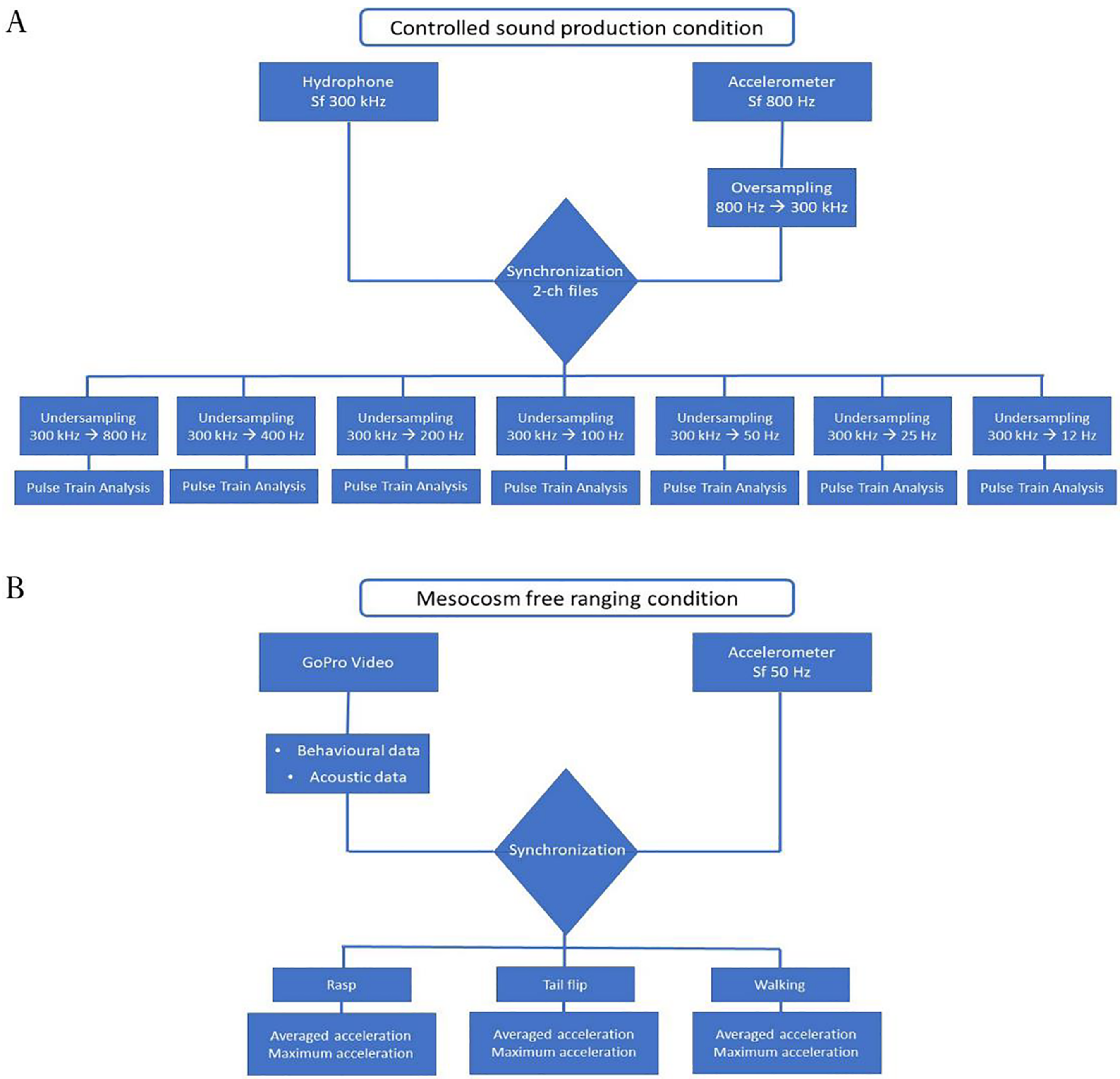

Fig. 1. Flowcharts that show the analysis process followed for (A) controlled sound production and (B) mesocosm free ranging conditions.

the maximum value for both acceleration and acoustic vectors.

$$\text{First channel: } A^2_{norm} = \frac{A^2}{\max(A^2)} \qquad \text{Second channel: } RelV^2_{norm} = \frac{RelV^2}{\max(RelV^2)}$$

In order to evaluate the efficiency of accelerometer in recording rasp signals at different frequencies, the 800 Hz 2-ch files were downsampled at sample frequencies generally used to monitor marine animal behaviours: 400 Hz, 200 Hz, 100 Hz, 50 Hz, 25 Hz and 12 Hz.

All data were visually displayed and inspected by an expert operator following Patek and Oakley (2003) and Buscaino et al. (2011a) sound description, in order to highlight and mark the presence of acoustic events ("rasp") in acoustic data. To count the number of impulses within each rasp individuated in acoustic (NAI) and acceleration (NAcI) data, a pulse train analysis (Avisoft SASlab Pro) was conducted adapting the threshold independently for each channel. The count processing was carried out independently for each acceleration sample frequency considered. All analysis stages are drawn in Fig. 1A.

2.3. Mesocosm free ranging condition

2.3.1. Experimental set-up

A 4000 l circular PVC tank with the same characteristic of the storage tank was set up as mesocosm with sand and rocks arranged in dens. Two cameras (GoPro Hero 4) were placed underwater during observation phases. After one week of acclimation period, 6 lobsters (CL of 81.0 ± 4.7 mm, 3 male and 3 female) were individually tagged with accelerometer (frequency 50 Hz). An external mark made of white nail painting according to a scheme pattern (e.g. one spot at the base of the left antenna, one in the right one, two spots in one antenna) was applied in order to easily recognize each lobster during the video clip analysis.

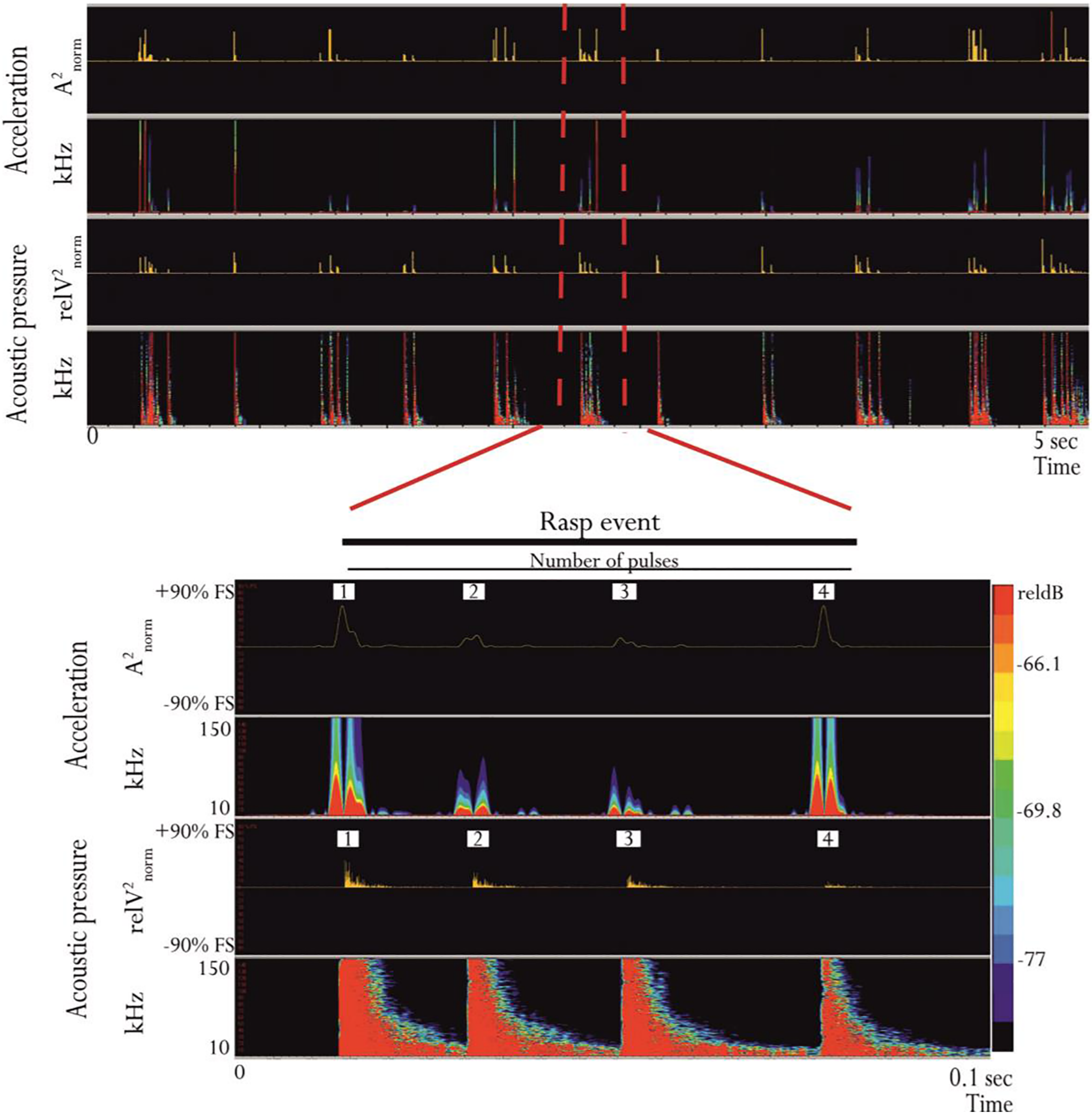

Fig. 2. On the top: Example of the two synchronized channels: 5 s of waveform (in yellow) and spectrogram (FFT length: 256, window: Hamming) respectively of acceleration and acoustic data with maximum sample frequency. Below: Zoom of waveform and spectrogram (FFT length: 256, window: Hamming) of one rasp event recorded respectively from acceleration and acoustic data. Labels on the top indicate the counted impulses for the event.

An *Octopus vulgaris* inside a net box was introduced into the experimental tank to stimulate lobster in emitting sound and performing tail flipping (escape reaction to a predator *sensu* Lavalli and Herrnkind, 2009).

2.3.2. *Video and audio analysis*

The lobster behaviour was analysed through the video screening, following a focal animal-sampling method (Altmann, 1974). An ethogram was build a priori identifying three different behavioural categories: the sound production from a rasp, the tail flip movement, and the walking behaviour. The starting and ending moment of several rasps, tail flip movements and walking behaviours were noted and used to individuate the relative acceleration data. In order to individuate the exactly starting and ending moment of acoustic emission, the acoustic data of the GoPro was extrapolated and the resulted oscillograme was used to determine the emission. All visual and acoustic screening was carried out using VideoPad (NCH Software v 5.10).

The acceleration raw data were converted to m/s^2. A scalar value was obtained following the formula:

$$A = \sqrt{(A_x^2 + A_y^2 + A_z^2)}$$

Video and acceleration data were synchronized using the most intense event as marker, for each behavioural event found through the

Table 1
Descriptive statistics of number of rasps event and (Mean ± Standard Deviation – SD) of number of impulses within a rasp, recorded for each trial from acoustic and acceleration data sampled at different sample frequencies (Sf).

	Trial	Acoustic data	Acceleration data						
		Sf 300.000 Hz	Sf 800 Hz	Sf 400 Hz	Sf 200 Hz	Sf 100 Hz	Sf 50 Hz	Sf 25 Hz	Sf 12 Hz
N. of Events and Mean (± SD) of Impulses	1	23	23	23	23	23	23	23	23
		10 (10,14)	10,83 (10,56)	9,74 (9,046)	5,96 (5,06)	3,04 (2,99)	2,30 (2,10)	1,83 (1,27)	0,96 (0,37)
	2	67	67	67	67	67	67	67	65
		6,97 (3,65)	6,99 (3,82)	7,16 (3,52)	6,21 (2,86)	2,42 (1,22)	1,45 (0,68)	0,96 (0,21)	0,91 (0,29)
	3	17	17	17	17	17	17	17	17
		14 (9,75)	9,71 (7,57)	8,65 (6,17)	6,41 (3,83)	3,53 (2,43)	1,65 (0,79)	0,88 (0,49)	0,94 (0,24)
	4	73	73	73	73	73	73	71	67
		4,07 (4,47)	4,88 (3,42)	5,36 (3,78)	4,58 (2,49)	2,04 (1,09)	1,18 (0,51)	1 (0,17)	0,99 (0,12)
	5	67	67	67	67	67	67	67	67
		12,69 (9,76)	7,75 (5,00)	7 (4,33)	5,63 (2,90)	2,51 (1,43)	1,51 (0,91)	1 (0,17)	0,97 (0,24)
	6	66	66	66	66	66	66	66	66
		3,63 (3,56)	2,3 (1,83)	2,53 (2,13)	2,38 (1,99)	1,47 (1,11)	0,92 (0,62)	0,79 (0,45)	0,64 (0,52)
	7	56	56	56	56	56	56	56	56
		13,80 (8,017)	8,73 (4,71)	6,48 (4,18)	3,75 (1,87)	2,04 (1,03)	1,32 (0,64)	0,95 (0,23)	0,91 (0,29)
	8	36	36	36	36	36	36	36	35
		14,86 (13,60)	8,86 (7,17)	9,69 (7,17)	7,19 (4,80)	2,64 (1,77)	1,67 (1,04)	1,14 (0,35)	0,91 (0,28)

video data screening, the relative interval of acceleration data was extrapolated and the averaged and maximum value of acceleration was computed. All analysis stages are drawn in Fig. 1B.

2.4. Statistical analysis

2.4.1. Controlled sound production condition

To evaluate the goodness of estimations by the two different instruments, a simple linear regression between number of impulses recorded by the hydrophone and the ones registered with accelerometer at different frequencies was used. Predictive power of regressions was evaluated using a goodness-of-fit criterion that depends on prediction errors. For each of the n individual samples available, a prediction for the number of impulses was obtained from its observed accelerometer peaks number and the linear model fitted to the remaining points; the proportional distance between the prediction obtained and the observed acoustic impulse counts was used as a prediction error for that observation ("one item-out crossvalidation", Linhart and Zucchini, 1986). Median and 90th percentile of observed errors were used as measures of the predictive power of different regression models for the seven frequencies (800, 400, 200, 100, 50, 25, 12 Hz).

2.4.2. Mesocosm free ranging condition

The values of averaged and maximum acceleration were tested for normal distribution using Shapiro-Wilk normality test. Since the data were not normally distributed (Averaged acceleration: $w = 0.63p < 0.001$; Maximum acceleration: $w = 0.80p < 0.001$), in order to compare the values for the three behavioural categories considered, the Kruskall-Wallis rank sum test and the multiple comparisons Dunn's post-hoc test were performed.

3. Results

3.1. Controlled sound production condition

All the lobsters involved in the experiment produced sound when stimulated. In total, we recorded 405 rasp events composed by 3630 acoustic impulses during 8 trials, the average (± s.d.) duration of each trial was 143 ± 126 s. The average number of acoustic impulses (NAI ± s.e.) per rasp event was 8.99 ± 0.44. In Fig. 2, the waveform and spectrogram (FFT length: 256, window: Hamming) of 5 s at 300 kHz of synchronized acceleration (on top) and acoustic (on bottom) data are showed. Rasp events and impulse counts are showed in details in Table 1.

There is an evident absolute correspondence between acoustic and acceleration events independently by the sample frequency used. In detail, while the N. of rasp events remains equal both for acoustic and acceleration data sampled at different frequencies (except for the sampling frequency of 12 Hz, Table 1). Differently, the correspondence between acoustic and acceleration impulses (NAI vs NAcI) is inversely proportional to the sample frequency. In Fig. 3 an example of rasp emission recorded with different sample frequency of accelerometer is showed.

R^2 of correlation and the number of detected impulses within a rasp decreased with sampling frequency (Fig. 4, Table 2). While the algorithm never failed to detect a rasp event at the different down sampled frequencies (Table 3), the estimated prediction error to detect impulses within each rasp increased while the sampled frequency decrease.

3.2. Mesocosm free ranging condition

A total of 46 behavioural events were identified from the video analysis, in particular: 18 events of walking behaviour, 15 tail flip movements, and 13 rasp acoustic events. Behavioural categories chosen are significantly different for both averaged and maximum acceleration values (Averaged acceleration: $\chi^2 = 23.10$, $df = 2$, $p < 0.001$; Maximum acceleration: $\chi^2 = 27.90$, $df = 2$, $p < 0.001$) (Figs. 5 and 6). The rasp events show a distinct pattern of acceleration, with values significantly higher respect other categories (Figs. 5 and 6).

4. Discussion

The results of this study have proven three-axial accelerometers are able to detect sound production events in the European spiny lobster *P. elephas*. All the estimations from accelerometer (800 Hz) and acoustic devices perfectly matched in terms of rasp event, while highly overlapped considering the numbers of impulses per rasp. In particular, under the highest accelerometer sampling frequency (800 Hz) the accelerometer was able to register even a single impulse within a rasp event, with a good correspondence ($R^2 = 0.717$, $p < 0.0001$ – see Table 2) and low median of predictive error (0.33 – see Table 3). Nonetheless, as the accelerometer recording frequency decreased (from 800 down to 12 Hz), the correspondence between mechanical and acoustical impulses falls dramatically just under 400 Hz ($R^2 = 0.094$ and median of predictive error = 0.65 – see Tables 2 and 3) but the sound production event itself remains evident and clearly recognizable even at 12 Hz (see Table 1). Accelerometers are often used in studies where the sampling frequency of the device depends on the technology

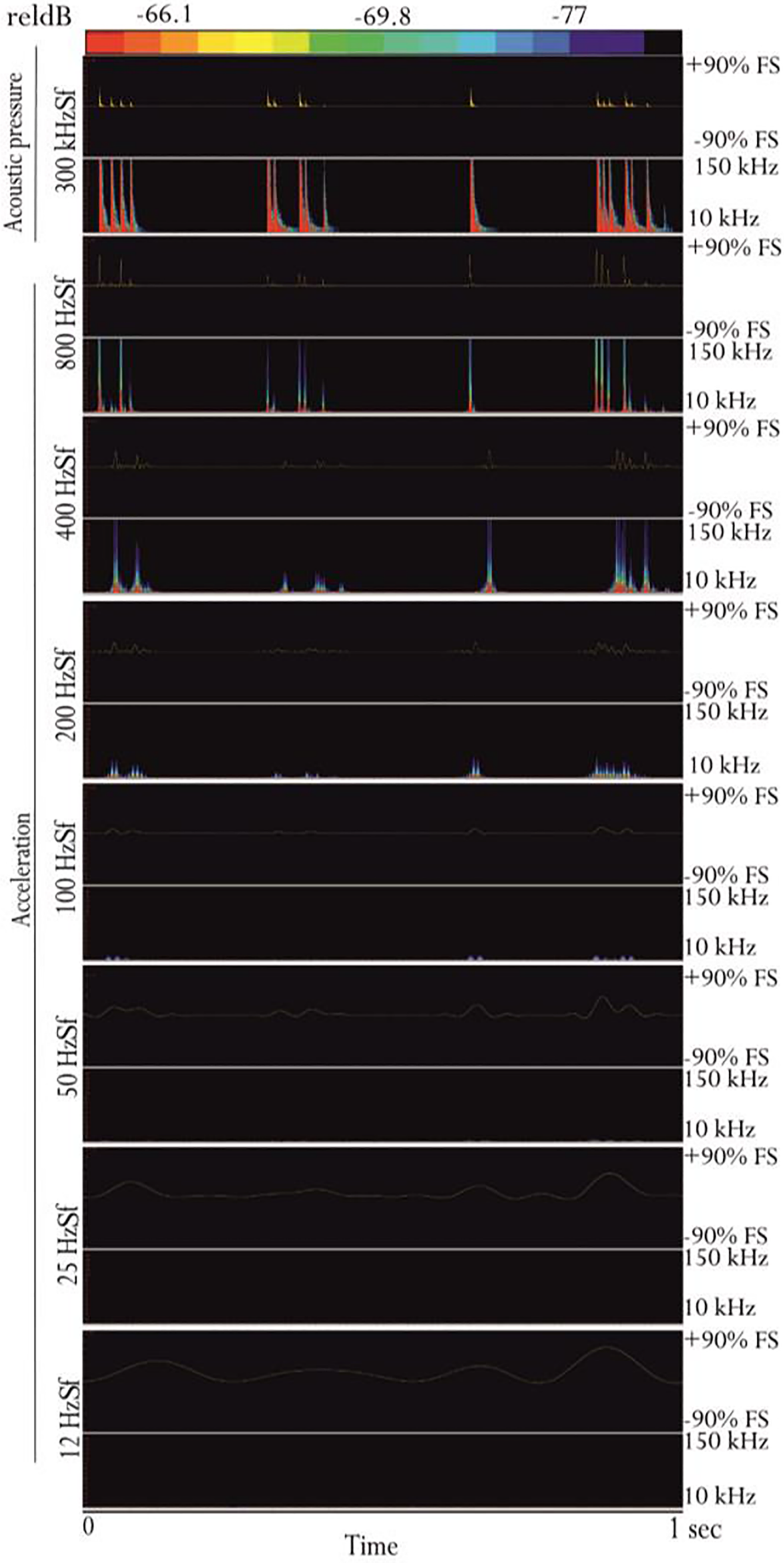

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Fig. 3. Waveform (on the top) and spectrogram (on the bottom) of four rasp events recorded with hydrophone and accelerometer using different sample frequencies (Sf). The waveforms are expressed in relV$^2_{norm}$ for acoustic pressure data and A$^2_{norm}$ for accelerator data.

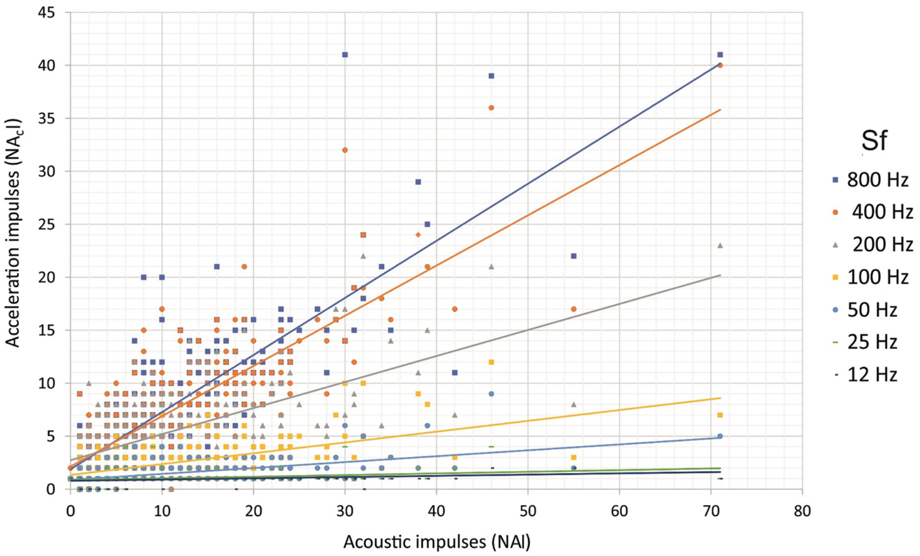

Fig. 4. Scatter plot and linear regressions of number of acoustic impulses counted (N_{AI}) and relative acceleration impulses (N_{AcI}) at different sample frequencies (Sf).

Table 2
Results of linear regression models considering the number of acoustic impulses (NAI) counted as independent variable and the number of acceleration impulses (NAcI) counted using different sample accelerometer frequencies (Sf) as dependent variable (*** = $p < 0.0001$).

Dependent variable (NAcI) Vs NAI	Beta	t	R^2	p
NAI (sf 800 Hz)	0.847	31.920	0.717	***
NAI (sf 400 Hz)	0.818	28.588	0.670	***
NAI (sf 200 Hz)	0.646	16.975	0.417	***
NAI (sf 100 Hz)	0.581	14.340	0.338	***
NAI (sf 50 Hz)	0.533	12.654	0.284	***
NAI (sf 25 Hz)	0.294	6.151	0.086	***
NAI (sf 12 Hz)	0.307	6.409	0.094	***

Table 3
Median and 90th percentile of predictive error for the linear regression between accelerometer and acoustic impulse counts.

	800 Hz	400 Hz	200 Hz	100 Hz	50 Hz	25 Hz	12 Hz
Median	0.33	0.34	0.51	0.59	0.58	0.66	0.65
90th percentile	1.19	1.45	2.02	3.8	3.57	7.57	3.97

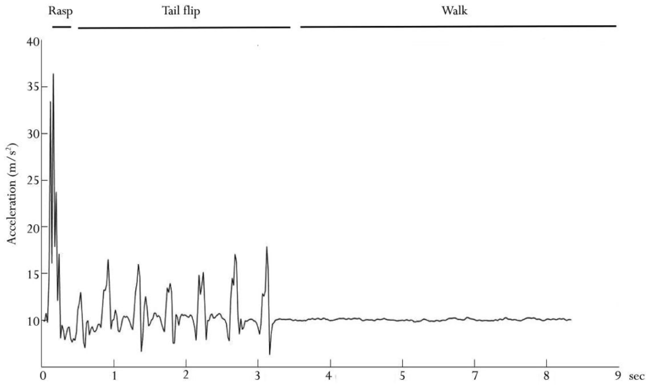

Fig. 5. Acceleration signal for each of the three behavioural categories (Rasp, Tail flip, Walk) identified.

(power, storage, etc.) and the size of the animal (according to the rule of 2% tag-load). Securing high-frequency data generally implies a larger battery requirement and a larger storage capability, each of which increases the tag dimensions (Broell et al., 2013). Different studies conducted using accelerometer suggest that frequencies between 10 and 50 Hz offer a good compromise between amount/accuracy of data and battery requirement, even if for fast moving behaviours, such as feeding strikes and escape responses in fishes, higher frequencies are required (Broell et al., 2013). Our findings are in line with this, each impulse within a rasp is a brief but very fast (high acceleration) phenomenon that needs high recording frequencies (> 400 Hz) to be properly described. The number of impulses in each rasp can be highly variable but this phenomenon is still poorly investigated and no evidences are available to assess its ecological meaning. Considering, instead, the ecological role of sound production in this species (antipredatory response, intraspecific communication), the chance to detect rasp events even using an accelerometer set at low sample frequency, becomes crucial in ecology and ethology studies. Furthermore, since the accelerometer is glued onto the carapace, vibration is directly transmitted to the accelerometer along the three dimensions, leading to only register lobster body vibrations. This characteristic allows, not only to record a clear signal that is not distorted by other noises in the environment, but also to identify rasps for a particular lobster (the ones carrying the device) what is not possible using a hydrophone in both aquaria or natural habitat studies. Moreover, the accelerometer methodologies could allow the assessment of each specimens sound contribution to the biological components of the soundscape (Farina, 2014; Buscaino et al., 2016; Ceraulo et al., 2018). In order to automatically classify different behaviour, including sound activity, it's proven that to build a behavioural library directly with the same animal to test, highly increase the efficiency of any algorithm used (Kawatsu et al., 2009).

To our knowledge, this study is the first attempt of rasp detection with 3-axial accelerometers in this or related species, for this reason any direct comparison with other studies with Palinuridae species, unfortunately, is not possible. Henninger and Watson (2005) combined both acoustic and accelerometer technique to characterize sound production in the clawed American lobster *H. americanus*. Even if the sound production mechanism in this species significantly differs from the one of the European spiny lobster, the approach of using both techniques

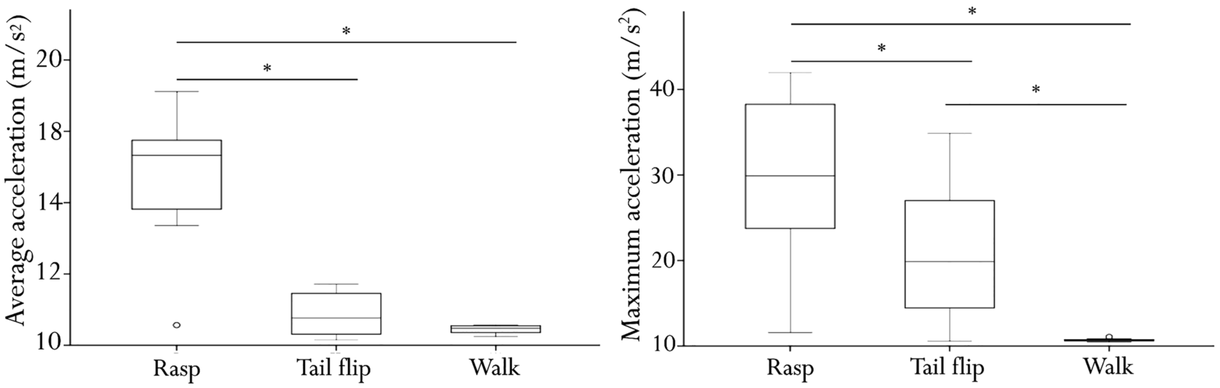

Fig. 6. Box plot of averaged and maximum acceleration values for each behavioural category (Rasp, Tail flip, Walk) considered. The stars indicate the significant statistical differences ($p < 0.001$) between groups.

turned out to be even so a success. Furthermore, the results from the mesocosm experiment, confirmed that accelerometer data lead possible to discriminate three of the most important behavioural contexts displayed by the European spiny lobster in a fine resolution scale that is difficult to obtain even using video data. This strongly supports the application of accelerometers in ethological studies also in wild condition. Goldbogen et al., (2014) in a study on baleen whales used the same approach. In their study, whale calls were simultaneously recorded on both accelerometers and hydrophones fixed in the whale fin. Their results are in line with those reported in the present study, confirming as hydrophone and accelerometer data perfectly match in terms of events. Furthermore, the accelerometer tag allowed the authors to discriminate the sound produced by the tagged whale. This is problematic by using only acoustic tag when more specimens are present, because the typical long-range propagation of low-frequency calls makes barely distinguishable tagged whale sounds from those of nearby animals. Describing animal behaviour of cryptic, nocturnal or aquatic animals has been a challenging task for researchers for decades. The use the 3-axial accelerometer provides a new tool to describe, at least in part, behaviour of aquatic animals in their natural environment with no other means to be studied. Methodologies similar to those developed here, used in combination with other biologging sensors, could allow the determination of many aspect of both biological and ecological life traits with important implications for various habitat management strategies. The example provided here to quantify some of the most important lobster behaviours, could be considered a stepping stone to assess accurate activity budget for free living individuals and for future studies about predator attack events, sound emission for intraspecific communication, and many other aspects of this partially cryptic and aquatic benthonic key species.

Moreover, the recently estimation of underwater noise intensity became a crucial issue to understand the effects of it on ecosystem and species levels (Hawkins and Popper, 2017; Celi et al., 2014; Filiciotto et al., 2014, 2016; Papale et al., 2015; Viola et al., 2017). Then, using accelerometers could contribute to evaluate the effects of noise pollution on lobsters in their natural environment.

Our findings provide an important knowledge to optimize the use of accelerometers in marine ecology studies with consequent advantages also from the economic point of view. In the last years such kind of information have been obtained using acoustic equipment with high costs of acquisition both in terms of instruments and logistic, accelerometers could represent a technical solution ten folds cheaper.

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