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Profitability of the Mediterranean and NE Atlantic new target sea cucumber species: some repercussions for their fisheries management

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The term profitability can be understood as the ratio in percentage between fresh weight of animals and the dry weight of the obtained bêche-de-mer depending on the body wall thickness of sea cucumbers and water content. Specimens decrease their weight and length considerably, when they are processed. However, scarce information about profitability of commercial sea cucumber from Mediterranean and NE Atlantic has been published until now. In this study, we focused on *Holothuria tubulosa, Holothuria polii, Holothuria mammata* and *Holothuria arguinensis.*

For most of the species considered, a good lineal regression was found between eviscerated length (EL) *vs* eviscerated weight (EW), and EW *vs* dried weight (DW); however, *H. arguinensis* showed a high dispersal of data and low regression coefficients.

The highest profitability (20.57 % ± 4.40) was registered on *H. arguinensis* and the second one (15.36 % ± 2.68) on *H. polii*. *H. mammata* and *H. tubulosa* showed lower profitability (11.95 % ± 0.54 and 10.75 % ± 0.55, respectively). Significant differences were found between profitability values of the studied species. Some implications for fisheries management were deduced from the relationships between profitability *vs* EW.

[Keywords: bêche-de-mer; Fishery; Holothuria sp; Mediterranean and NE Atlantic regions; Recovery rates]

Introduction

In the recent years, NE Atlantic and Mediterranean sea cucumbers are being considered an important fishery resource[1-4], mainly *Holothuria polii, Holothuria tubulosa, Holothuria mammata, Holothuria arguinensis, Holothuria forskali* and *Parastichopus regalis.*

In Turkey sea cucumbers are commercially harvested since 1996[5]. At first, this fishery was focused on *Parastichopus regalis* as "by-catch species" using trawls; but later, it was developed as sea cucumber fishery focused on *H. polii, H. tubulosa* and *H. mammata*[1-2,4]. In NE Spain, *P. regalis* is caught since XIX century[6], although in the last decade, this species is being considered a delicacy, and its internal muscle bands are valued as one of the most expensive products[6-7]. The fishery of this species is also important in other Spanish regions like Galicia (NW Spain), with catches around 7.429 Kg in 2016 worth 16.191 euros[4]. *H. forskali* is another new target sea cucumber species, caught during the last three years from Turkey[8] and Atlantic Spanish waters, being its capture legalized in Galicia (NW Spain) reaching catches close to 60.000 Kg in 2016 (January-September)[4]. In Andalusia (S Spain), *H. arguinensis* is caught illegally and exported to China by 10 companies[3-4]. In Portugal, holothurians are being sold illegally, mainly *H. arguinensis* and another species like *H. forskali, H. mammata* and *H. sanctori*, with variable prices (from 70 to 350 €/kg)[3-4].

Most of these new target species are processed as bêche-de-mer (BDM; *iriko* in Japanese, *hai-som* in Chinese or *trepang* in Indonesian)[8], a dried product consumed as a delicacy and for health benefits[9-10]. The most important markets for BDM are China, Hong Kong, Taiwan, Singapore and Malaysia[11]. Its commercial value depends on quality of product (appearance, shape, consistence, smell, etc) and species[2-3]. The profitability (= recovery rate) meaning "the relationship in percentage between fresh weight of sea cucumbers and the dry weight of resulting BDM" could depend on their body wall thickness and water content[3]. The sea cucumber body wall has 60 % of water, which is highly lost during processing[9]. The other 40 % is mainly protein that maintains the body shape and favors holothurian feeding, breathing, burrowing and defense against predators (Cuvierian tubules)[12-13].

After processing, specimens of tropical sea cucumbers lose weight and length considerably[14-16]. It was registered a 90-97 % weight reduction depending on the species[14]. Recent studies on *Holothuria scabra* demonstrated that independent of the initial size, a 91 % reduction in weight and 52 % in length were recorded after processing[16]. Some authors[17] carried out a study on quality features of *Holothuria tubulosa* from Turkey, considering several drying methodologies. Significant differences between fresh, boiled and dried samples ($p < 0.05$) were found: weight and length of fresh sea cucumbers decreased to 50 % after boiling, while 86 % and 55 % decreasing respectively, at the end of the sun drying period.

Therefore, our aim was to evaluate the recovery rates of the most important commercial sea cucumber species from NE Atlantic and Mediterranean, including *Holothuria polii, H. mammata, H. tubulosa* and *H. arguinensis.* These recovery rates would change between species which could have important implications for their fishery management, such as the determination of the minimum harvest sizes for each species to ensure that BDM reaches a right length for commercial sales. Also, these data could help for a better estimation of the fresh weight of sea cucumber sold by fishers and companies.

Materials and Methods

In 2015, specimens of *Holothuria polii* (n=50), *H. mammata* (n=50) and *H. tubulosa* (n=50) were obtained from fishermen working in Akbuk region (Turkey). Each individual was eviscerated and recorded its weight (EW ± 0.01 g) and length (EL ± 0.1 mm); later, animals were processed according Turkish commercial method[8]. First, sea cucumbers were boiled in sea water during 30 minutes at 100 ºC, later they were dried during 30 minutes in a drying room. Then, dry weight (DW ± 0.01 g) and dry length (DL ± 0.1 mm) were recorded. In 2016, *H. arguinensis* individuals (n=35) were caught from Ria Formosa (S Portugal) and processed according to the Turkish methodology, however, including a longer drying time (48 h) as its body wall is thicker than that found in the other species.

Relationships between EW *vs* EL, and EW *vs* DW were established. Profitability [Prof (%) = 100* dry weight / eviscerated weight] was estimated for each species. Values were compared using Kruskal-Wallis test and Tukey and Kramer (Nemenyi) test since profitability had not a normal distribution (Shapiro-Wilk normality test; W = 0.81454, p-value = 4.527e-14)[18].

Results

For all species considered, a good lineal regression was found between EL and EW, ranged from R^2 = 0.83 for *H. polii* to R^2 = 0.97 for *H. tubulosa;* similar results were registered when EW *vs* dried weight (DW) were compared (R^2 = 0.94 for *H. polii*; R^2 = 0.97 for *H. tubulosa;* R^2 = 0.99 for *H. mammata*). However, *H. arguinensis* showed a high dispersal of data and a very low regression coefficient for the first relationship (EL *vs* EW: R^2 = 0.11); although the regression improved when EW *vs* DW were compared (R^2 = 0.75).

H. arguinensis had the highest profitability (20.57 % ± 4.40)followed by *H. polii* (15.36 % ± 2.68) (Fig. 1). Lower profitability was recorded for

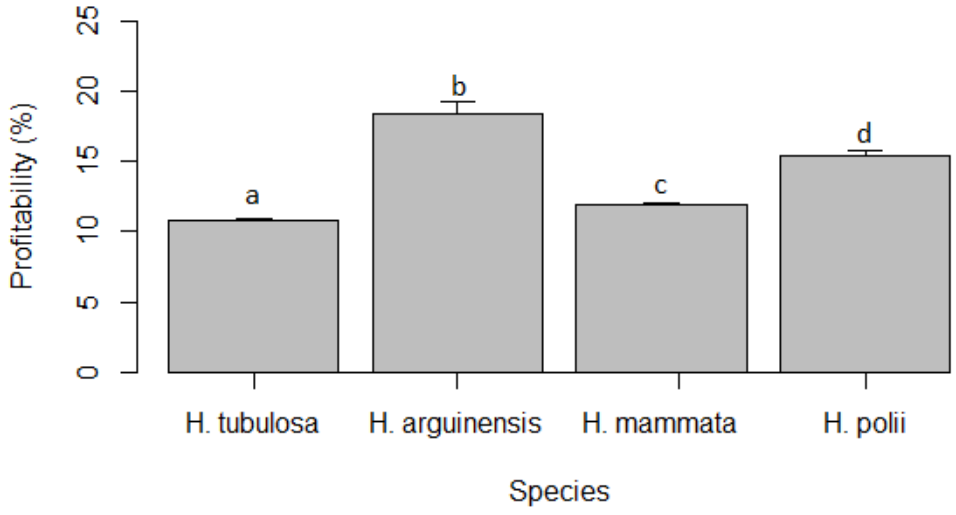

Fig. 1 — Mean profitability and significance in different studied species of sea cucumbers (different letters are indicating significant differences: $p < 0.05$).

H. mammata and *H. tubulosa* (11.95% ± 0.54 and 10.75 % ± 0.55, respectively). Kruskal-Wallis test found significant differences between the profitability values of species (Kruskal-Wallis chi-squared = 139.03, df = 3, p < 2.2e-16). Pairwise comparisons of profitability values using Tukey and Kramer (Nemenyi) test, detected significant differences among all comparisons (p <0.05; Table 1).

The relationship between profitability *vs* EW provided interesting patterns depending on species (Fig. 2). *H. polii* showed a different profitability according to the EW of individuals: 10-15 % for specimens ranged from 45 to 75 g and 15-18 % for animals with 70-110 g. The profitability was more constant for *H. tubulosa* (10-12 % for individuals with 70-180 g) and *H. mammata* (12-13 % for 40-160 g), without showing variations with weight. *H. arguinensis* showed variable values of profitability oscillating from 13 % to 28 %; these percentages were independent of the individuals' weight.

Table 1 — Pairwise comparisons of profitability values using Tukey and Kramer (Nemenyi) test with Tukey-Dist approximation for independent samples (differences were considered significant if p<0.05).

	H. arguinensis	*H. mammata*	*H. polii*
H. mammata	2.e-10	-	-
H. polii	0.0234	0.0002	-
H. tubulosa	4.0e-14	2.5e-05	3.2e-14

Discussion

Results demonstrated that *H. arguinensis* has a higher profitability than the other species, likely because *H. arguinensis* shows thicker body wall and higher wet weight than individuals of another species with same length[3]. *H. polii* is the second species with high profitability: it showed the most fine thickness of body wall, but a low water content. *H. arguinensis* and *H. polii* showed higher or similar profitability than the published values for other sea cucumber from New Caledonia such *Actinopyga echinites* (15.55 %), *Actinopyga spinea* (13.47 %), *Holothuria lessoni* (15.18 %), *Holothuria whitmaei* (18.14 %) and *Actinopyga palauensis* (16.75 %) (profitability values calculated from EW *vs* DW shown in[18]). *H. tubulosa* and *H. mammata*, presented similar or lower profitability than the previous species. However, lower values of profitability were recorded from another sea cucumber species from Fiji (profitability values calculated from EW *vs* DW shown in[9]) including

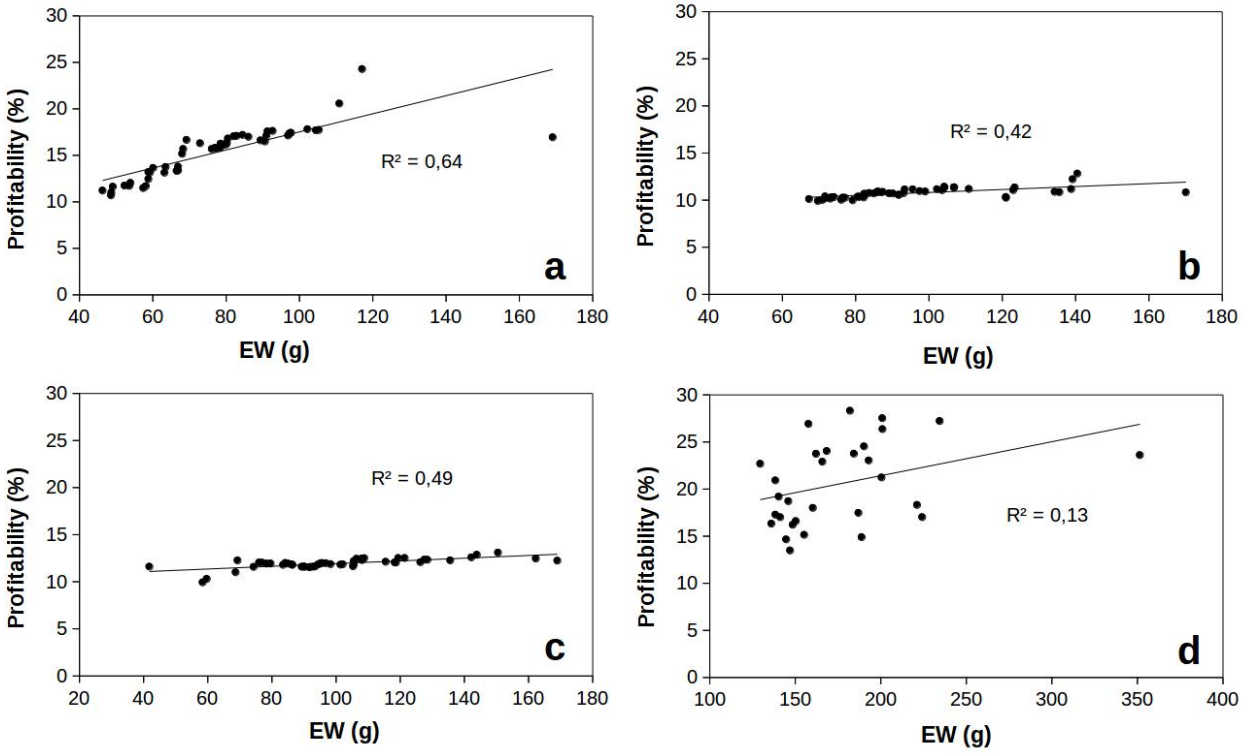

Fig. 2 — Linear regression between profitability *vs* eviscerated weight (EW) for the different sea cucumber species. (a: *Holothuria polii;* b: *Holothuria tubulosa*; c: *Holothuria mammata*; d: *Holothuria arguinensis*).

Actinopyga lecanora (9.97 %), *Actinopyga mauritania* (5.97 %), *Actinopyga miliaris* (6.62 %), *Bohadschia argus* (3.16 %), *Holothuria fuscogilva* (11.14 %), *Holothuria scabra* (8.89 %) and *Thelenota ananas* (6.86 %). Lower profitability value was also obtained from *Holothuria whitmaei* (11.56 %) sampled in Fiji[10] as compared with the previous one registered by[19] for the same species from New Caledonia (18.14 %). Differences on the geographical origin of specimens could affect the profitability values considering the possible variations on food resources for sea cucumbers; also the different processing methodologies used in both studies could have influence on dry weight and therefore on the recovery rates calculated[10,19]. Another studies have evaluated the recovery rates between wild and cultured *H. scabra* specimens, not showing significant differences[20]. The values of the recovery rates considering the gutted weight ranged from 5.0 % to 5.6 % for culture and wild specimens respectively; these values increased when fresh weight was considered (8.8 % and 9.6 %).

According to the exploitation criteria[3] (length, weight and their relationships) and profitability, *H. arguinensis* is the best target species among the selected ones in this study. However, its very restricted geographical range[21-22] and illegal catches during the last years decreased its wild stocks[4] and therefore, should be considered for its further fishery management planning.

On the other hand, our results are showing that *H. polii* has different profitability depending on eviscerated weight of individuals, increasing the recovery rate (15-18 %) for heavier specimens (70-110 g). So, taking in account the result about *H. polii* profitability, along with the fecundity rate and maturity weight[23], it could be interesting to manage the catch of a lower number of individuals but with higher weight which will provide higher profitability for companies. For *H. tubulosa* and *H. mammata* the profitability rates are maintained constant with independence of the eviscerated weight such as it was registered on *H. scabra* and *Isostichopus badionotus* previously[16,24]. Therefore, it could be recommended to focus on the fisheries efforts for lighter and younger individuals (but not juveniles) avoiding the catch of large individuals that show a higher reproductive potential. *H. arguinensis* showed the highest average of profitability but also a high variability when the relationship between EW *vs* profitability was analyzed, thus making in to impossible for the improvement of its fishery management according to this parameter.

Also, it is important to take in account the size of the species, as largest or shortest individuals could be favorite in the Asian market and therefore this could affect their prices[25-26]. So, further information from Asian markets should be obtained on this subject for the NE Atlantic and Mediterranean target species, in order to extrapolate our data to the fishery management of these species.

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