Discarded fish on the Spanish Mediterranean coast: influence of season on fatty acids profiles

MARÍA DOLORES SUÁREZ, MARÍA ISABEL SÁEZ, MIGUEL ÁNGEL RINCÓN-CERVERA, LUIS HIDALGO, JOSE LUIS GUIL-GUERRERO

doi: 10.12681/mms.24909

To cite this article:

SUÁREZ, M. D., SÁEZ, M. I., RINCÓN-CERVERA, M. ÁNGEL, HIDALGO, L., & GUIL-GUERRERO, J. L. (2021). Discarded fish on the Spanish Mediterranean coast: influence of season on fatty acids profiles. Mediterranean Marine Science, 22(2), 232–245. https://doi.org/10.12681/mms.24909
Discarded fish on the Spanish Mediterranean coast: influence of season on fatty acids profiles

María Dolores SUÁREZ1, María Isabel SÁEZ1, Miguel Ángel RINCON-CERVERA1, Luis HIDALGO1 and Jose Luis GUIL-GUERRERO1

1 Departament of Biology and Geology, CEIMAR. University of Almeria, 04120, Almeria, Spain
2 Institute of Nutrition and Food Technology (INTA), University of Chile. 7830490, Macul, Santiago, Chile
3 Area of Food Technology, Department of Agronomy. University of Almeria, 04120, Almeria, Spain

Contributing Editor: Stelios SOMARAKIS

Received: 1 October 2020; Accepted: 12 February 2020; Published online: 31 March 2021

Abstract

This work focused on determining the fatty acid (FA) composition of commonly discarded fish on the Spanish Mediterranean coast in winter and summer to assess their potential use as raw sources of very long-chain polyunsaturated fatty acids (VLCPUFAs). Total n-3 VLCPUFA content significantly varies depending on capture season, and values were higher in winter for Pomadasys incisus (1.36 g/100 g), Chelidonichthys lucerna (1.67 g/100 g) and Trachinus draco (2.04 g/100 g), while Pagellus acarne had larger n-3 PUFA amounts in summer (3.89 g/100 g). Generally for most species, monounsaturated FA, eicosapentaenoic acid (20:5n-3) and total FA had higher values in summer, while both the n-3 VLCPUFA fraction and DHA content were higher in winter. Knowledge of these changes allows the processes for their proper use as valuable PUFA sources to be adjusted. The discarded fish herein studied could be generally considered to be raw n-3 VLCPUFAs sources.

Keywords: Fish composition; discarded fish; fatty acid profiles; Mediterranean coast; n-3 very long-chain PUFAs; seasonal changes.

Introduction

Global extractive fishing catches have remained at around 90 million tons per year for the last two decades (FAO, 2018). It has been estimated that about 10.8% of this production is discarded as by-products (Gilman et al., 2020). Fish discard is the portion of total organic matter of animal origin that is wasted or dumped at sea. The main reasons for discarding fish are certain species’ low commercial value (no target species) and legal restrictions for species of commercial interest because fish is regulated by quotas (Total Allowable Catch, TAC) and size-regulated fish (Minimum Conservation Reference Size (MCRS)).

The European Commission has proposed plans to promote the use of more selective fishing practices and to, thus, reduce the amount of discarded fish. The discarded fish biomass is a rich source of high-quality compounds of pharmaceutical, nutritional or biotechnological interest (Rincón Cervera et al., 2014; Nascimento et al., 2015; Blanco et al., 2018). Furthermore, using fish discards not only mitigates the drawback of their disposal, but also prevents negative effects on biological resources and ecosystems.

The marine biomass is generally rich in n-3 very long-chain polyunsaturated fatty acids (n-3 VLCPUFA), such as eicosapentaenoic acid (EPA, 20:5n-3) and docosahexaenoic acid (DHA, 22:6n-3) (Nascimento et al., 2015). These nutrients are conditionally essential for humans because of their well-proven health benefits (Simopoulos, 2004), particularly those related to the prevention of cardiovascular and neurological diseases. In addition, both EPA and DHA are precursors of lipid mediators (eicosanoids and docosanoids, respectively), which have anti-inflammatory properties (Calder et al., 2017).

Nowadays, searching for alternative sources of n-3 VLCPUFA is mandatory, and growing interest is being shown in fish discard and seafood industrial waste given their high content of these important nutrients (Orban et al., 2011; Rincón-Cervera et al., 2014; Nascimento et al., 2015; Blanco et al., 2018; Kandyliari et al., 2020), and also because using discarded fish can prevent overfishing commonly consumed n-3 VLCPUFA-rich fish species.

The lipid content and fatty acid (FA) profile of fish vary according to different variables like seasonality, geographical area, size, sex and sexual maturation (Shirai et al., 2002). The most significant environmental factors are water temperature, fluctuation in food availability and
reproductive cycle (Kołakowska et al., 2003).

The main types of fishing gear operating in the Alboran Sea are artisanal (small scale) fisheries. Nevertheless, the most significant one in terms of both the volume of catches and economic value is bottom trawling. Trawling fishing gear can have a stronger impact on the marine ecosystem and may lead to higher discarding rates than other gear operating at open sea (Sánchez et al., 2004; Tsagarakis et al., 2014; Urra et al., 2017). The main discarded species of Alboran fisheries include some of the species herein analyzed, such as seabream (Pagellus acarne, P. erythrinus), mackerel (Trachurus mediterraneus, T. trachurus) and horse mackerel (T. trachurus) as the main discarded species (Carbonel et al., 2018). In addition to these species, red porgy (Pagrus pagrus), bogue (Boops boops) and picarels (Spicara spp.) are also some species discarded by bottom trawl fisheries in the Western Mediterranean subregion (Sánchez et al., 2004; FAO, 2018).

Both the lipid fraction and FA content of discarded marine fish have been reported in some species, such as the gadiform family (Falch et al., 2006a, b), sea sardine (Sardina pilchardus), mackerel (S. colias), horse mackerel (T. trachurus) (García-Moreno et al., 2013) and nakedbanded gaper (Champsodon nudivittis) (Ozyilmaz, 2016). The FA profiles from fish processing industry by-products have also been studied (Rincón-Cerevera et al., 2014; Nascimento et al., 2015; Kandylari et al., 2020). However, more research is needed to improve knowledge on FA composition and its seasonality for a wide range of species discarded on the Mediterranean coast. Furthermore, profound knowledge of the total amount of these species’ discarded portion is necessary to assess their potential as EPA and DHA sources, and to ensure their large-scale production (Rustad et al., 2011).

This study elucidates the biometric parameters and FA composition of discarded fish species from pelagic and benthic habitats on the East Mediterranean coast of Spain caught in winter (January) and summer (June) to hypothesize that these species could be potential marine sources of n-3 VLCPUFA.

### Material and Methods

#### Fish collection and sampling

Fish were taken from a bottom trawl vessel operating on the East Mediterranean coast of the Iberian Peninsula (N Alboran Sea) (Fig. 1) in winter (January) and summer (June) of 2018. The surface water temperature was 15.3°C and 20.0°C, respectively. The discarded fish species were identified according to the available literature. Samples of each species (8 fish each) were stored separately in polyethylene bags with identifying labels and preserved in ice until they reached the laboratory. Then fish were frozen at -20°C until further processed.

Thirteen discarded species were selected, most from the demersal habitat: blackspot sea bream (Pagellus bogaraveo), common pandora (Pagellus erythrinus), axillary seabream (Pagellus acarne), red porgy (Pagrus pagrus), bogue (Boops boops), red gurnard (Chelidonichthysculus), tub gurnard (Chelidonichthys lucerna), greater weever (Trachinus draco) and bastard grunt (Pomadasysincisus). Other species were pelagic (Mediterranean horse mackerel, Trachurus mediterraneus; horse mackerel, Trachurus trachurus) or benthopelagic (blotted picnicarel, Spicara maena and picnicarel, Spicara smaris). Table 1 lists the analysed species, including their habitats, depth range, feeding type, reproductive characteristics, data of sizes upon first maturity and legal fishing limits and Minimum Conservation Reference Size (MCRS, Annex III to Regulation EC No. 1967/2006).

#### Biometric parameters

Eight fish of each species were selected to determine the biometric parameters.

Total length (TL, cm) from the tip of the snout to the tip of the longer lobe of the caudal fin was recorded by a measuring board. Total body weight (TBW, g), liver weight (LW, g), digestive weight (DW, g) and fillet weight (FW, g) were recorded using a balance to the

**Fig. 1:** Map of the Northern Alboran Sea (Geographical Subarea 1 according to General Fisheries Commission for the Mediterranean, GFCM division. Obtained from D-maps.com website: https://d-maps.com/carte.php?num_car=33776&lang=en).
Table 1. List of fish species analysed in this work including habitats and reproduction characteristics.

| Scientific name       | Habitats           | Code | Usual depth range | Types of bottom | feeding                                                                 | Reproduction                        | Spawning season | Range of size at first maturity (cm) | Size at first maturity (cm) | MCRS (cm) |
|-----------------------|--------------------|------|-------------------|-----------------|------------------------------------------------------------------------|--------------------------------------|------------------|-------------------------------------|---------------------------|-----------|
| *Pagellus bogaraveo*  | benthopelagic      | SBR  | 150 - 300 m       | rocks, sand, mud | Omnivorous, feeding mainly on crustaceans, mollusks, worms and small fish| protandrous hermaphroditism         | January to June | 31.4                                 | 20-30                     | 33        |
| *Pagellus erythrinus* | benthopelagic      | PAC  | 50 - 100 m        | rock, gravel, sand, mud | Small crustaceans, mollusks, small fishes | protogynous hermaphroditism          | From April to July | 13-16                                | 12.8-25.2                  | 15        |
| *Pagellus acarne*     | benthopelagic      | SBA  | 40 - 100 m        | seagrass beds and sand | Small crustaceans, mollusks, small fishes | protandrous hermaphroditism          | From April to July | 16                                    | 18-21.7                   | 17        |
| *Pagrus pagrus*       | demersal or semipelagic | RPG  | 10 - 80 m        | rock, rubble, sand | Crustaceans, fishes, and mollusks | protogynous hermaphroditism          | From April to July | 24                                    | 24                        | 18        |
| *Boops boops*         | demersal           | BOG  | 0 - 100 m         | sand, mud, rocks, seaweeds | Omnivorous (crustaceans) also planktophagous | protogynous hermaphroditism          | from January to May | 14.3                                  | 11.9 - 17                  | 11^4      |
| *Trachurus mediterraneus* | pelagic            | HMM  | 5 - 250 m        | Small crustaceans, shrimps, small fishes | Small crustaceans, shrimps, small fishes | dioic, external fertilization, multiple spawner | from March to April | 20                                    | 19.1                      | 15        |
| *Trachurus trachurus* | pelagic            | HOM  | 100 - 200 m       | Fish, crustaceans, and cephalopods | Fish, crustaceans, and cephalopods | dioic, external fertilization, multiple spawner | From May to September | 21-30                                | 19 - 30                    | 15        |
| *Spicara maena*       | pelagic-neritic    | BPI  | 30 - 130 m        | *Posidonia* beds, sand, muddy | Zooplanktivorous preference to animal food | protogynous hermaphroditism          | from March to June | 10.3                                  | 11.5-13                    | 11,5      |
| *Spicara smaris*      | pelagic-neritic    | SPC  | 15 - 170 m        | *Posidonia* beds, muddy bottoms | Zooplanktivorous preference to plant food | protogynous hermaphroditism          | from March to June | 9.1                                   | 11-13                     | 9 - 11^3   |
| *Chelidonichthys cuculus* | demersal          | GUS  | 30 - 250 m        | sand and gravel, crag, and rocks | Benthic crustaceans, other invertebrates and bottom-dwelling fishes | dioic, external fertilization | from January to April | 26.6 (16.8^5)         | 25                        | 15^6      |
| *Chelidonichthys lucerna* | demersal           | GUU  | 20 - 318 m        | sand, muddy sand, gravel bottoms | Fish, crustaceans and mollusks | dioic, external fertilization | from May to September | 24.7 (14.4^7)          | 18-21.6                    | >18^9     |

Continued
nearest ±0.01 g. The data from the linear and weight determinations were used to calculate the following indices: Condition factor (%) = 100 * TBW/TL^3; HIS: Hepatosomatic index (%) = 100 * LW/TBW; DSI: Digestivesomatic index (%) = 100*(DW/TBW) and Fillet yield % = 100*(2*FW/TBW).

**Fatty acid analyses**

Simultaneous oil extraction and transesterification were carried out according to a previous work (Guil-Guerrero et al., 2013). Samples of the thawed whole fish (n=3) were homogenized using a laboratory blender. Then a representative aliquot (50 mg wet weight) was weighed in a 10-ml test tube. After transesterification, fatty acid methyl esters (FAME) were analyzed by a Focus GC (Thermo Electron. Cambridge, UK), equipped with a flame ionization detector and an Omegawax 250 capillary column (30 m x 0.25 mm ID x 0.25 μm film thickness) (Supelco, Bellefonte, PA, USA). The oven temperature was 90ºC (1 min), 10ºC/min to 100ºC (3 min), 6ºC/min to 260ºC (5 min). The injector temperature was set at 250ºC with a split ratio of 50:1 and an injection volume of 4 μL. The detector temperature was set at 260ºC and the carrier gas (nitrogen) flow was 1 mL/min. The peak area of the internal standard was used as a reference to quantify the mass of each FA in the resulting chromatograms. Fatty acid profiles were reported as FA percentages of the total FA available in samples. Peaks were identified by their retention times, obtained for known FAME standards (PUFA No. 1, 47033 from Sigma, St. Louis, USA).

**Quality index**

FA were grouped into families (SFAs, MUFAs, n-6 and n-3 PUFAs), which were calculated and expressed as percentages and the total amount of each FA group as 100 g of fish tissue.

Both the Atherogenic Index (AI) and Thrombogenic Index (TI) were calculated according to Ulbricht & Southgate (1991), and the PUFA/SFA Index was also obtained.

IA indicates the relation between the main pro-atherogenic FA and the main anti-atherogenic FA.

\[
IA = \frac{(12:0 + 4*14:0 + 16:0)}{[\text{n-6} + \text{n-3}] \text{ PUFA} + 18:1 + \text{the sum of the other MUFA}],}
\]

IT shows the tendency of clots forming in blood vessels. This is defined as the relation between the pro-thrombogenic (saturated) and the anti-thrombogenic FA (MUFA, n-6 PUFA, n-3 PUFA).

\[
IT = \frac{(14:0+16:0+18:0)}{(0.5*18:1 + 0.5*\Sigma \text{MUFA} + 0.5*\text{PUFAs n-6} + 3* \text{PUFAs n-3} + (n-3/n-6)}.
\]

**Statistical Analysis**

The results are reported as mean value±S.D. The effect of the categorical variables “fish species” and “sampling time”, and their possible interactions, were determined for each parameter by fitting a general linear statistical model (GLM analysis), which relates...
the measured parameters to predictive factors. Data were processed by a one-way ANOVA and least-square means were tested for differences by Fisher’s least significant difference (LSD) procedure. When the results were expressed as a percentage (e.g. FAs), data were normalized using the arcsine transformation of their square root prior to the statistical analysis. Unless otherwise specified, a 95% significance level was considered to indicate statistical differences ($P<0.05$). All the statistical analyses were conducted with specific software (Statgraphics Plus 4.0, Statistical Graphics Corp., Rockville, Maryland, USA).

Results

Biometric Parameters

The results of the biometric parameters determined for the different fish species in several sampling months are shown in Table 2. The smallest size (length and weight) of the fish sampled in January was found for $P.$ acarne, $P.$ erythrinus and $C.$ cuculus, whereas the biggest size went to $B.$ boops, $T.$ draco and $P.$ incisus. In June, low values were still observed for $C.$ cuculus and high ones for $B.$ boops, $P.$ bogaraveo and $P.$ erythrinus obtained intermediate values and $P.$ acarne was the biggest species. The $P.$ pagrus specimens also had high weight values in all the measurements.

The condition factor (CF) relates total length and total weight, and indicates how elongated a fish is. The CF values were above 1.0 in most of the studied species, except $B.$ boops, $T.$ mediterraneus, $T.$ trachurus, $S.$ smaris and $T.$ draco whose values were below 0.8. The highest CF values in January were for $P.$ pagrus, $C.$ cuculus and $P.$ incisus, while $P.$ acarne and $C.$ cuculus had the highest CF values in June. The last species also showed the highest HSI in January and June.

Fatty acid content

FA content (g FA/100 g tissue) and proportion (% of total FAs) were included for the data collected in January and June (Table 3 for Sparidae pelagic members, Table 4 for $Trachurus$ and $Spicara$ spp. and Table 5 for demersal species).

The species with the highest FA contents in January were $P.$ incisus (7.3 g FA/100 g fish) and $T.$ draco (5.7 g FA/100 g fish), whereas the lowest FA contents were found for $P.$ bogaraveo (1.3 g FA/100 g fish) and $P.$ acarne (1.9 g FA/100 g fish).

The June sampling gave higher FA contents than in January. $P.$ acarne (10.9 g FA/100 g fish) and $B.$ boops (3.0 g FA/100 g fish) had the highest and lowest FA content, respectively. In general, this parameter significantly increased in June for all the species. However, this fact was not verified in the species caught only in June, and not in January.

Fatty acid profiles

When considering the FAs grouped according to their degree of unsaturation, saturated FAs (SFA) were between 30% and 38% of total FAs, MUFAs were approximately between 10% and 33%, and PUFAs went from 17.4 to 46.8% for the n-3 series and from 5.2 to 11.3% for the n-6 series.

In January, the lowest proportion of SFAs (29.7%) was found in $S.$ smaris and the highest (38.0%) in $P.$ acarne. MUFAs had low values in $P.$ erythrinus and $S.$ smaris (over 9.7%), with high values in $S.$ maena (33%) and $P.$ incisus (40.2%). The n-3 PUFA proportion ranged from 17.4% in $P.$ incisus to 46.9% in $S.$ smaris. $S.$ smaris, $P.$ acarne and $P.$ pagrus had the highest n-6 PUFA proportions (10.6, 10.8 and 11.3%, respectively), while the lowest proportions went to $T.$ mediterraneus and $T.$ draco (over 5%). The n-3/n-6 ratio ranged from 3.3 in $P.$ incisus to 7.4 in $T.$ mediterraneus.

Significantly high MUFA, and low SFA and PUFA fractions, were observed in $Sparidae$ spp in June compared to January (Table 3). The drop in n-3 PUFA was less marked than that of n-6 PUFA and, consequently, the n-3/n-6 ratio was higher in summer in most of the species of this family, except $P.$ erythrinus. The other evaluated pelagic or demersal species displayed different trends, but the n-3/n-6 ratio significantly rose in all cases.

The lowest proportion of SFAs in June was for $C.$ cuculus (29.1%), $S.$ smaris and $P.$ erythrinus (around 29.8%), and the highest (34.0%) for $T.$ trachurus. MUFAs had low values in $B.$ boops (8.4%) and high values in $P.$ acarne (22.4%) and $P.$ pagrus (19.2%). The n-3 PUFA proportion ranged from 34.9% in $P.$ acarne to 50.4% in $B.$ boops. The highest n-6 PUFA proportion was for $P.$ erythrinus and $P.$ pagrus (11.6 and 11.3%), while the lowest went to $T.$ trachurus (4.5%). The n-3/n-6 ratio ranged from 3.6 in $P.$ erythrinus to 9.6 in $T.$ trachurus.

Quality parameters

The lowest n-3/n-6 ratios in January were for $P.$ incisus (3.3), $P.$ pagrus (3.4), $S.$ maena (3.7) and $P.$ acarne (3.9), whereas the highest values were found in $T.$ draco (6.9) and $T.$ mediterraneus (7.4). In June, the highest values went to $B.$ boops (8.5) and $T.$ trachurus (9.6), and $P.$ erythrinus had the lowest value (4.4).

The AI values in January ranged from 0.33 ($S.$ smaris) to 0.56 ($T.$ mediterraneus and $S.$ maena), and values increased in June for $B.$ bogaraveo, $T.$ trachurus and $S.$ smaris. TI ranged from 0.19 ($S.$ smaris) to 0.42 ($P.$ incisus) in the January sampling, and values lowered for several species in June ($B.$ boops, $S.$ maena and $C.$ cuculus).

The highest PUFA/SFA ratio in the January sampling was observed in $S.$ smaris (1.59), followed by $T.$ trachurus (1.35), $P.$ bogaraveo (1.30) and $P.$ erythrinus (1.31), while the lowest value was for $S.$ maena (0.80). The ratio significantly lowered in all the species sampled in June.

The FA groups (g/100 g of tissue) are depicted in Figure 2. In the January sampling, $P.$ incisus had the highest
Table 2. Biometric parameters of different species in the January and June sampling (mean ± SD; n=8).

| Species                        | JAN       | JUN       |
|-------------------------------|-----------|-----------|
| Pagellus bogaraveo (Blackspot sea bream) | 11.8±0.4  | 15.9±0.2  |
| Pagellus erythrinus (Common pandora)     | 10.6±1.4  | 16.4±0.8  |
| Pagellus acarne (Axillary seabream)       | 20.8±0.4  | 21.2±1.5  |
| Pagrus pagrus (Red porgy)              | 11.8±0.4  | -         |
| Boops boops                        | 10.6±0.7  | 11.6±0.9  |
| Trachurus mediterraneus (Mediterranean horse mackerel) | 20.8±0.6  | 16.5±0.8  |
| Horse mackerel                    | -         | 18.0±1.4  |
| Trachurus trachurus (Horse mackerel)    | 13.3±0.4  | 11.4±1.1  |
| Spicara maena (Blotched picarel)      | 11.4±1.0  | -         |
| Spicara smaris (Picarel)             | 11.8±0.6  | -         |
| Chelidonichthys cuculus (Red gurnard)  | 15.0±0.4  | 17.7±5.3  |
| Chelidonichthys lucerna (Tub gurnard)  | 27.1±2.7  | 45.5±0.7  |
| Trachinus draco (Greater weever)      | 22.6±1.3  | 23.8±2.5  |
| Pomadasys incisus (Bastard grunt)     | 74.4±3.5  | 74.5±37.5 |
| Total length (cm)                  | 11.8 de ± 0.4 | 17.5±0.5  |
|                                  | 11.8 de ± 0.4 | 17.5±0.7  |
| Total weight (g)                   | 17.19±0.4 | 17.19±0.4 |
|                                  | 15.0±0.4  | 15.0±0.4  |
| Condition factor (%)               | 1.0±0.2   | 1.2±0.2   |
|                                  | 1.2±0.2   | 1.2±0.2   |
| HSI2 (%)                         | 0.7±0.3   | 0.7±0.3   |
|                                  | 0.7±0.3   | 0.7±0.3   |
| DSI3 (%)                         | 3.9±0.3   | 3.9±0.3   |
|                                  | 4.8±0.2   | 4.8±0.2   |
| Fillet yield (%)                  | 43.4±0.6  | 61.7±0.6  |
|                                  | 49.1±1.4  | 64.8±1.87 |

Values with different superscripts indicate significant differences (p<0.05) attributable to different species in a sampling time * indicate significant differences attributable to sampling time for each specie. (p<0.05).

1Condition factor % = (Total weight (g)/(Total length (cm)))
2Hepatosomatic index % = 100*(Liver weight (g)/Total weight (g))
3Digestive-somatic index %= 100*(Digestive weight (g)/Total weight (g))
4Fillet yield % = 100*(2*Lateral fillet weight (g)/Total weight (g))
Table 3. Muscle fatty acid content (g FA/100 g wet weight) and profiles of main FA (FA% of total FAs) of Sparidae species in January and June sampling (Values are reported as mean ± SD, n=3)

| Pagellus bogaraveo | Pagellus erythrinus | Pagellus acarne | Pagrus pagrus | Boops boops |
|-------------------|--------------------|----------------|--------------|-------------|
|                   | January | June | January | June | January | June | January | June | January | June |
| FA content (g FA/100 g fish) | 1.8±0.2 | 5.4*±0.4 | 2.4±0.1 | 3.5*±0.4 | 1.9±0.3 | 10.9*±0.4 | 2.0±0.3 | 5.5±0.2 | 2.2±0.1 | 3.0±0.1 |

FA profile (% of total FA)

|          | January | June | January | June | January | June | January | June | January | June |
|----------|---------|------|---------|------|---------|------|---------|------|---------|------|
| 14:0 (MA) | 2.3c±0.2 | 4.7*±0.4 | 1.4*±0.1 | 1.5*±0.3 | 1.8*±0.1 | 3.9*±0.1 | 2.2±0.1 | 3.7±0.2 | 2.8±0.1 | 2.2±0.2 |
| 15:0 (PDA) | 1.6±0.2 | 0.9*±0.4 | 0.8*±0.0 | 1.3*±0.4 | 2.4±0.2 | 0.9*±0.4 | 0.8*±0.0 | 0.7*±0.2 | 2.5±0.1 | 0.7±0.1 |
| 16:0 (PA) | 20.6±0.7 | 17.1*±0.3 | 21.6±0.3 | 19.1±0.3 | 25.8±0.1 | 18.2*±0.2 | 19.9±0.1 | 18.1*±0.8 | 21.9*±0.3 | 21.3±0.8 |
| 16:1n-7(POA) | 1.7±0.1 | 5.6*±0.4 | 3.0±0.1 | 5.4*±0.1 | 2.7±0.3 | 6.5*±0.1 | 5.4±0.1 | 7.0±0.1 | 3.8±0.0 | 2.7±0.1 |
| 18:0 (SA) | 9.2±0.1 | 8.4*±0.2 | 9.3±0.6 | 7.7*±0.2 | 8.0±0.8 | 7.3±0.1 | 8.5*±0.6 | 7.6±0.1 | 6.7±0.1 | 7.5±0.1 |
| 18:1n-9 (OA) | 7.4±0.1 | 8.3*±0.1 | 5.6±0.2 | 6.8*±0.1 | 5.4±0.3 | 11.9*±0.1 | 7.6*±0.2 | 8.9±0.2 | 7.7*±0.1 | 5.3±0.2 |
| 18:1n-7 (VA) | 2.2±0.2 | 5.7*±0.3 | 3.9±0.1 | 3.0*±0.1 | - | 4.8±0.1 | 3.8±0.1 | 4.3±0.1 | 3.6±0.1 | 2.4±0.1 |
| 18:2n-6 (LA) | 1.6±0.1 | 1.4±0.2 | 1.4±0.1 | 1.5±0.6 | 2.9±0.1 | 1.4±0.1 | 2.4±0.1 | 1.1±0.1 | 0.5±0.1 | 1.5±0.1 |
| 18:3n-3 (ALA) | 1.0±0.1 | 0.8±0.1 | 0.8±0.0 | 0.9*±0.1 | 0.7±0.2 | 1.1±0.0 | 0.5±0.1 | 1.5±0.1 | 0.6±0.1 | 0.9±0.1 |
| 18:4n-3 (SDA) | 0.2±0.1 | - | 0.1±0.3 | - | - | 0.9±0.1 | - | 0.4±0.2 | 0.3±0.1 | 0.7±0.2 |
| 20:1n-9 (EPA) | 0.2±0.1 | 3.5*±0.1 | 1.1±0.3 | - | 0.2±0.1 | 3.4*±0.1 | 1.3±0.1 | 3.3*±0.1 | - | 0.4±0.1 |
| 20:4n-6 (AA) | 5.0±0.1 | 2.6*±0.1 | 6.3±0.1 | 4.4*±0.2 | 4.8±0.5 | 2.5±0.1 | 4.9±0.2 | 2.7±0.1 | 2.9±0.1 | 2.3±0.1 |
| 20:4n-3 (DGLA) | 0.4±0.1 | 0.7±0.0 | - | - | 0.2±0.1 | 0.7±0.1 | 1.6±0.1 | 0.8±0.1 | - | 0.6±0.1 |
| 20:5n-3 (EPA) | 7.6±0.1 | 12.7±0.4 | 11.3±0.2 | 8.1±0.1 | 4.6±0.3 | 11.4±0.2 | 7.7±0.1 | 13.2±0.1 | 9.5±0.5 | 7.4±0.1 |
| 22:5n-3 (DPA) | 2.3±0.1 | 4.9±0.2 | 3.5±0.1 | 4.8±0.1 | 3.5±0.2 | 4.1±0.1 | 3.2±0.1 | 4.1±0.1 | 1.8±0.2 | 2.6±0.2 |
| 22:6n-3 (DHA) | 32.7±0.1 | 18.5±0.2 | 27.6±0.5 | 28.2±0.3 | 31.7±0.3 | 17.7±0.2 | 25.7±0.2 | 19.8±0.2 | 27.6±0.8 | 39.1±0.8 |
| Unidentified | 0.3±0.3 | 0.6±0.2 | 0.5±0.1 | 0.9±0.1 | 0.4±0.2 | 0.6±0.1 | 0.7±0.1 | 0.6±0.3 | 0.5±0.6 | 0.7±0.3 |

Values with different superscripts indicate significant differences attributable to different species: lower case in January sampling and capital letter in June sampling; * indicate significant differences attributable to sampling time for each species: (p<0.05).

1Saturated fatty acids, 2monounsaturated fatty acids, 3polyunsaturated fatty acids n-3, 4polyunsaturated fatty acids n-6, 5AI: Atherogenic Index= (12:0 + 4*14:0 + 16:0) / [(n-6 + n-3) PUFA + 18:1 + the sum of other MUFA], 6 TI: Thrombogenic Index= (14:0 + 16:0+18:0) / (0.5*18:1 + 0.5*ΣMUFAs + 0.5*PUFAs n-6 + 3*PUFAs n-3 + (n-3/n-6).
Table 4. Muscle fatty acid content (g FA/100 g wet weight) and profiles of main FA (% of total FAs) of *Trachurus* and *Spicara* spp in January and June sampling (Values are reported as mean ± SD, n=3).

|            | *Trachurus mediterraneus* | *Trachurus trachurus* | *Spicara maena* | *Spicara smaris* |
|------------|---------------------------|-----------------------|-----------------|-----------------|
|            | January | June | January | June | January | June | January | June |
| FA content (g FA/100 g fish) |          |      |          |      |          |      |          |      |
| 14:0 (LA)  | 2.7a ± 0.1 | 2.1b ± 0.2 | 2.4a ± 0.1 | 2.5b ± 0.2 | 3.1b ± 0.1 | 2.6a ± 0.2 | 3.4b ± 0.1 | 2.2a ± 0.2 |
| 16:0 (SA)  | 8.4b ± 0.4 | 7.2b ± 0.0 | 8.0b ± 0.1 | 7.5a ± 0.8 | 8.5a ± 0.5 | 7.2b ± 0.1 | 6.4a ± 0.4 | 6.2a ± 0.0 |
| 16:1 n-7 (POA) | 3.8b ± 0.1 | 2.3a ± 0.1 | 3.1b ± 0.1 | 7.8c ± 0.2 | 4.8a ± 0.4 | 1.5a ± 0.0 | 3.1b ± 0.1 | 3.1b ± 0.1 |
| 18:0 (SA)  | 8.4b ± 0.4 | 7.2b ± 0.0 | 8.0b ± 0.1 | 7.5a ± 0.8 | 8.5a ± 0.5 | 7.2b ± 0.1 | 6.4a ± 0.4 | 6.2a ± 0.0 |
| 18:1 n-9 (OA) | 6.8b ± 0.3 | 5.8a ± 0.1 | 10.7b ± 0.0 | 22.9c ± 0.3 | 10.8b ± 0.1 | 5.7b ± 0.0 | 8.5a ± 0.5 | 8.5a ± 0.5 |
| 18:1 n-7 (VA) | 2.8b ± 0.2 | 2.4ab ± 0.1 | 3.0b ± 0.1 | 3.1b ± 0.1 | 1.9a ± 0.1 | 2.6a ± 0.1 | 3.1b ± 0.1 | 3.1b ± 0.1 |
| 18:2 n-6 (LA) | 1.5a ± 0.3 | 2.0b ± 0.1 | 1.6ab ± 0.3 | 2.1b ± 0.2 | 1.8b ± 0.3 | 2.2b ± 0.1 | 1.4a ± 0.1 | 1.4a ± 0.1 |
| 18:3 n-3 (ALA) | 0.8b ± 0.1 | 0.4a ± 0.1 | 0.8b ± 0.1 | 0.8b ± 0.1 | 0.8b ± 0.1 | 0.8b ± 0.1 | 0.8b ± 0.1 | 0.8b ± 0.1 |
| 20:4 n-3 (AA) | 1.6a ± 0.2 | 2.0b ± 0.1 | 1.2a ± 0.1 | 1.8b ± 0.3 | 2.0ab ± 0.2 | 2.0ab ± 0.2 | 2.0ab ± 0.2 | 2.0ab ± 0.2 |
| 20:5 n-3 (DPA) | 2.8c ± 0.1 | 3.3d ± 0.2 | 2.3b ± 0.1 | 1.8ab ± 0.1 | 1.4a ± 0.1 | 1.2a ± 0.0 | 1.8ab ± 0.1 | 1.8ab ± 0.1 |
| 22:6 n-3 (DHA) | 30.1b ± 0.5 | 31.6c ± 0.2 | 30.1b ± 0.5 | 30.1b ± 0.5 | 28.2 A* ± 0.0 | 20.6 A* ± 0.0 | 28.2 A* ± 0.0 | 28.2 A* ± 0.0 |
| Unidentified | 0.3a ± 0.1 | 0.6b ± 0.4 | 0.4 A ± 0.3 | 0.2a ± 0.1 | 0.8 B ± 0.0 | 0.7 b ± 0.1 | 0.6 AB ± 0.3 | 0.6 AB ± 0.3 |

Values with different superscripts indicate significant differences attributable to different species: lower case in January sampling and capital letter in June sampling; * indicate significant differences attributable to sampling time for each species. (p<0.05).

|            | January | June | January | June |
|------------|---------|------|---------|------|
| SFA        | 36.5c ± 0.9 | 32.4b ± 0.2 | 34.6b ± 0.4 | 36.4b ± 0.4 |
| MUFA       | 13.6b ± 0.3 | 10.5b ± 0.3 | 14.1b ± 0.3 | 13.6b ± 0.3 |
| n-3 PUFA   | 40.9b ± 0.1 | 45.9b ± 0.1 | 43.3b ± 0.5 | 43.3b ± 0.5 |
| n-6 PUFA   | 5.6b ± 0.1 | 7.7b ± 0.2 | 4.5b ± 0.3 | 6.9b ± 0.2 |
| n-3/ n-6   | 7.4b ± 0.1 | 5.9b ± 0.5 | 9.6b ± 0.3 | 3.7b ± 0.0 |
| PUFA/SFA   | 0.55 ± 0.01 | 0.25 ± 0.01 | 0.22 ± 0.01 | 0.22 ± 0.01 |
| AI         | 0.55 ± 0.01 | 0.25 ± 0.01 | 0.22 ± 0.01 | 0.22 ± 0.01 |
| TI         | 0.55 ± 0.01 | 0.25 ± 0.01 | 0.22 ± 0.01 | 0.22 ± 0.01 |

Saturated fatty acids (SFA), monounsaturated fatty acids (MUFA), polyunsaturated fatty acids n-3 (PUFA), polyunsaturated fatty acids n-6 (PUFA n-6), PI: Polyunsaturated Index (PI = n-3 PUFA + n-6 PUFA), MUFA/SFA, AI: Atherogenic Index = (12:0 + 4*14:0 + 16:0) / [((n-6 PUFA + n-3 PUFA) + 18:1 + the sum of other MUFA], TI: Thrombogenic Index = (14:0+16:0+18:0) / (0.5*18:1 + 0.5*ΣMUFAs + 0.5*(n-6 PUFA + n-3 PUFA) + (n-3/n-6)).
Table 5. Muscle fatty acid content (g FA/100 g wet weight) and FA profiles (FA% of total FAs) of demersal species in January and June sampling (Values are reported as mean ± SD, n=3)

|                  | Chelidonichthys cuculus | Chelidonichthys lucerna | Trachinus draco | Pomadasys incisus |
|------------------|-------------------------|-------------------------|----------------|------------------|
|                  | January | June | January | June | January | June | January | June |
| FA content (g FA/100 g fish) | 2.9±0.2 | 4.8±0.1 | 4.7±0.2 | -     | 5.8±0.1 | -    | 7.3±0.2 | -    |
| FA profiles (FA% of total FA) |          |        |         |       |          |       |          |       |
| 14:0 (MA)        | 2.7±0.2 | 2.2±0.2 | 1.8±0.1 | -     | 3.1±0.3 | -    | 4.1±0.2 | -    |
| 15:0 (PDA)       | 0.9±0.2 | 0.7±0.2 | 0.6±0.1 | -     | 0.4±0.3 | -    | 0.6±0.2 | -    |
| 16:0 (PA)        | 22.3±0.1| 19.8±0.3| 21.2±0.6| -     | 21.4±0.4| -    | 22.3±0.8| -    |
| 16:1n-7(POA)     | 2.9±0.2 | 4.6±0.1 | 8.9±0.2 | -     | 6.0±0.1 | -    | 12.0±0.3| -    |
| 18:0 (SA)        | 7.1±0.1 | 6.5±0.1 | 7.3±0.6 | -     | 5.8±0.8 | -    | 6.9±0.8 | -    |
| 18:1n-9 (OA)     | 10.9±0.1| 11.9±0.3| 11.7±0.2| -     | 16.9±0.3| -    | 28.2±0.2| -    |
| 18:1n-7 (VA)     | 3.0±0.1 | 3.5±0.1 | 4.0±0.1 | -     | 2.4±0.1 | -    | -       | -    |
| 18:2n-6 (LA)     | 3.2±0.1 | 1.2±0.0 | 3.4±0.1 | -     | 2.3±0.1 | -    | 1.9±0.1 | -    |
| 18:5n-3 (ALA)    | 0.8±0.1 | 0.4±0.0 | 0.5±0.1 | -     | 0.9±0.3 | -    | 0.6±0.2 | -    |
| 18:4n-3 (SDA)    | 0.6±0.2 | 0.5±0.1 | 0.3±0.3 | -     | 1.1±0.4 | -    | 1.7±0.2 | -    |
| 20:1n-9 (EEA)    | 1.1±0.0 | 0.5±0.0 | 1.0±0.2 | -     | 0.7±0.1 | -    | 0.9±0.2 | -    |
| 20:4n-6 (AA)     | 2.0±0.1 | 2.8±0.0 | 2.8±0.4 | -     | 2.0±0.1 | -    | 2.2±0.2 | -    |
| 20:4n-3 (DGLA)   | 1.2±0.3 | 0.8±0.1 | 1.2±0.1 | -     | 1.0±0.2 | -    | 0.4±0.1 | -    |
| 20:5n-3 (EPA)    | 8.3±0.2 | 9.6±0.3 | 10.2±0.4| -     | 5.9±0.4 | -    | 7.0±0.3 | -    |
| 22:5n-3 (DPA)    | 1.9±0.1 | 3.7±0.2 | 2.2±0.2 | -     | 2.1±0.1 | -    | 1.9±0.1 | -    |
| 22:6n-3 (DHA)    | 27.7±0.6| 27.9±0.4| 21.2±0.0| -     | 26.1±0.8| -    | 7.6±0.3 | -    |
| Unidentified     | 0.5±0.4 | 0.7±0.1 | 0.2±0.1 | -     | 0.5±0.2 | -    | 0.5±0.2 | -    |
| MUFA 1           | 30.1±0.4| 29.1±0.4| 30.3±0.6 | -     | 30.4±0.1| -    | 33.3±0.6| -    |
| n-3 PUFA 2       | 16.8±0.3| 17.6±0.4| 24.6±0.1| -     | 24.3±0.2| -    | 40.2±0.8| -    |
| n-6 PUFA 3       | 40.5±0.4| 42.4±1.1| 35.1±0.2| -     | 35.8±0.5| -    | 17.4±0.5| -    |
| n-3/n-6 4        | 7.6±0.9 | 6.5±0.2 | 7.4±0.4 | -     | 5.2±0.6 | -    | 5.3±0.6 | -    |
| AI 5             | 0.52±0.01| 0.40±0.02| 0.44±0.01| -     | 0.51±0.04| -    | 0.60±0.03| -    |
| TI 6             | 0.23±0.00| 0.20±0.01| 0.24±0.01| -     | 0.23±0.00| -    | 0.42±0.00| -    |
| PUFA/SFA         | 1.21±0.05| 0.43±0.03| 1.14±0.06| -     | 1.17±0.05| -    | 0.52±0.01| -    |

Values with different superscripts indicate significant differences attributable to different species: lower case in January sampling and capital letter in June sampling; * indicate significant differences attributable to sampling time for each species (p<0.05).

Saturated fatty acids, monounsaturated fatty acids, polyunsaturated fatty acids n-3, polyunsaturated fatty acids n-6, \*AI: Atherogenic Index = \((12:0 + 4*14:0 + 16:0) / [(n-6 + n-3) PUFA + 18:1 + the sum of other MUFA]\), \* TI: Thrombogenic Index = \((14:0 + 16:0 + 18:0) / (0.5*18:1 + 0.5*ΣMUFAs + 0.5*PUFAs n-6 + 3*PUFAs n-3 + (n-3/n-6))\).
values for SFA (1.20 g/100g), MUFA (2.87 g/100g) and n-6 PUFA (0.39 g/100 g) contents. The n-3 PUFA values were also high for this species (1.36 g/100 g), but C. lucerna and T. dacro had larger amounts (1.67 g/100 g and 2.04 g/100 g, respectively). In June, SFA and MUFA displayed significant higher values. It is necessary to emphasize the marked increase observed in P. acarne for all the FA groups, and n-3 PUFAs are highlighted.

Discussion

Discarded species

Five of the species included in the present study (P. bogaraveo, P. erythrinus, P. acarne, P. pargus, B. boops) belong to the family Sparidae. They are demersal or semipelagic, and live above the continental shelf, usually down to a depth of about 100 m, although young individuals can be found nearer the shore. They feed on crustaceans, fish and mollusks (See Table 1). The first four species are among the main target species in the Mediterranean for their high commercial value (García et al., 2012). The commercial importance of bogue (B. boops) varies vastly depending on the area. In Spain, its commercial value is limited and it is, therefore, frequently discarded (Carbonell et al., 2018).

Trachurus spp. are pelagic fish of less commercial interest. They sometimes represent a very high percentage of the total capture for purse seine fishing, but are absent in trawl fishing in the Alboran Sea (García et al., 2012). T. mediterraneus is frequently located in shallow areas, while T. trachurus frequent bigger habitats. Species’ food habits are influenced by life cycle. Juveniles feed principally on plankton, while larger individuals prefer fish as prey.

Blotched picarel (S. maena) and picarel (S. smaris) belong to the family Centracanthidae and Greater weever (T. draco) is one of four species of the family Trachinidae. Although this species is of very little commercial interest, the scarcity of fishing resources, the high demand for fish products and new manufacturing techniques have led to a growing interest being shown in this species, and it is landed in practically all the ports along the Alboran Sea (Portillo Stempel et al., 2008). The commercial value of C. cuculus and T. draco is low on the Spanish coast, and they are sold together in a mixed fish category known as “morralla” (Ordines et al., 2014).

Bastard grunt (P. incisus) is one of the five species of the family Haemulidae, a species that is frequently discarded for its low commercial value (Pajuelo et al., 2003). Its presence in the Mediterranean Sea is relatively recent owing to the progressive warming of Mediterranean waters, which is why it has been considered an indicator of changing marine conditions toward “tropicalisation”.

Biometric parameters

Most sampled species did not exceed the Minimum Conservation Reference Size (MCRS, Annex III to Regulation EC No. 1967/2006). In this study, their size was smaller than the minimum legal size, under which fish should not be caught (Table 1), so they are discarded, and they include P. bogaraveo, P. erythrinus, P. pargus, T. mediterraneus, T. trachurus and C. cuculus. The summer samples of P. acarne (16.7 cm) and P. erythrinus (16.4 cm) were below the limits set by Tsikliras & Stergiou (2014) (21.7 cm and 25.2 cm, respectively). Therefore, the caught individuals were below the maturity size.

The larger B. boops size indicates that samples were
longer than upon their first maturity, but were discarded because their commercial value on the Spanish coast is low (Carbonell et al., 2018).

The *C. lucerna* specimens also had a longer total length (17.5 cm), which came close to the proposed minimum landing size (>18 cm, Özdemir et al., 2019). The total length of *Sparus* spp., *T. draco* and *P. incisus* samples was also longer than their MCRS (11.5 cm for *S. maena*, 11 cm for *S. smaris*, 14 for *T. draco*, 15.3 cm for *P. incisus*) for both sampling times, and the reason why these species are discarded is clearly their low commercial value. The condition factor (CF) relates length and weight, and most values were above 1.0, except for *B. boops*, *T. mediterraneus*, *T. trachurus*, *S. smaris* and *T. draco*, with values below 0.8. The length-weight ratio is normally affected by several factors; e.g., sampling season, food abundance, size, age, sex, reproductive period, muscle development and fat storage. The CF values did not significantly change between the winter and summer samplings for most studied species, which indicates isometric growth patterns. However, positive allometric growth was seen for *P. bogaraveo*, *P. acarne*, and *P. pagrus*, whose weight increased at a higher rate than their body length. Their CF values were significantly higher in June than in January, possibly because of the more marked increase in Digestive-somatic index (DSI) and Fillet yields (FY) rather than in these species’ length.

The length-weight ratio within one species can fluctuate between seasons due to the influence of temporal and/or spatial factors, such as temperature, salinity, food availability and composition. Such variations may also be due to the influence of reproductive processes on individual growth, although the species herein studied had not yet reached the reproductive stage.

Conversely, *S. maena* and, more importantly, *S. smaris* showed negative allometric growth, caused by a considerable increase in length and a significant decrease in digestive weight (perivisceral fat loss). This scenario may be due to changes in fish body shape that becomes more elongated throughout their life span. Reproductive status can also be influenced because the samples of both species were longer than they were upon first maturity. However, no mature gonads were found in any sample, possibly because it was the end of the reproductive season (from May to June).

**FA contents**

The species with higher FA contents (*C. lucerna*, *T. draco* and *P. incisus*) are essentially demersal. However, their habitat changes throughout the year. In spring, they are found in shallow water (El-Serafi et al., 2015 for *C. lucerna*; Portillo Strempel et al., 2008 for *T. draco* and Fehri-Bedoui & Gharbi, 2008 for *P. incisus*). The larger sizes shown by the samples of these species (bigger upon first maturity) indicated that they were adults, which could be related to their higher FA content. As these individuals were caught in January outside their spawning season, the presence of mature gonads was not observed in any sample. Several authors have reported that the larger fish size is, the higher lipid contents are (García Mesa et al., 2014).

A significant increase in the FA content was observed in June, which highlights *P. acarne* (10.9 g/100 g fish) and *T. trachurus* (6.0 g/100 g fish). These increases coincided with heavier body weight, especially in *Sparidae* species, whose weight practically doubled during the summer sampling. In some exception cases, the increases noted in the FA content and weight of *B. boops* were not as remarkable as they were in the other analyzed species, possibly because these individuals were adults in both samples, while the others were juveniles. Conversely, Morales-Medina et al. (2015) indicated significant changes in the lipid content throughout the year in *B. boops* (from 1.0% in spring to 6.0% in autumn), which of similar size to those herein analyzed.

The general increased FA content in summer agrees with those reported by several authors and could be because of increased feed intake owing to a higher metabolic rate at higher water temperatures (Yıldız et al., 2006). In addition, environmental changes and annual fluctuations influence food availability and composition which, in turn, affect the fish chemical composition (Orban et al., 2011), while the fish spawning season can also influence seasonal variations.

**Fatty acid profiles**

The proportion of SFAs was similar in most of the species studied in the January sampling (from 29.7% to 33.0% of total FA), but higher values were observed in *P. acarne* (38.0%). The most abundant FA of this family was palmitic acid (PA, 16:0), which agrees with previous works. Its accumulation has been explained by it constituting the major energy source for metabolism and growth (El Oudiani et al., 2019). PA reached its highest values in *S. maena* (24.4%) and *P. acarne* (25.8%). The *S. maena* case could be related to its above-mentioned bigger size and higher FA content. The differences found for *P. acarne* compared to other Sparidae family members may be due to varying feeding habits. Young fish from this family are pelagic, and this habitat is partitioned among different species to avoid diet overlapping.

For MUFA, all the species contained mainly oleic acid (OA, 18:1n-9), which agrees with previous reports (Aydin et al., 2013). High levels of palmitoleic acid (POA, 16:1n-7) were also found for several species, such as *S. maena* (7.8%), *T. draco* (6.0%), *P. incisus* (12.0%) and *C. lucerna* (8.9%). This spells a higher MUFA proportion in these species, especially in *P. incisus*, whereas the total MUFA proportion was higher than SFA and PUFA, unlike the trend observed in most of the remaining species (PUFA>SFA>MUFA). High MUFA levels in fish can indicate that they are carnivorous, and their diet is based on zooplankton, crustaceans (e.g. copepods) and mollusks (El Oudiani et al., 2019) because MUFA generally derive from marine copepods and other macrozooplankton (Arai et al., 2015).
$n$-$6$ PUFA was represented mainly by linoleic acid (LA, 18:2n-6) and arachidonic acid (ARA, 20:4n-6), which accounted for 9-11% of the total FAs in most studied species. In general, less $n$-$6$ PUFAs was found than other FA groups, which may reflect their lower level in marine lipids. This contrasts with that observed in the terrestrial environment. Conversely, the $n$-$3$ PUFA proportion was high (between 35% and 46% of total FAs) in most species, which coincides with previous studies on marine fish. DHA (22:6n-3) and EPA (20:5n-3) were the most representative $n$-$3$ PUFAs, and DHA was more abundant than EPA in most analyzed discarded species. These FA accumulate from marine microalgae and reach higher values in omnivorous fish (Loukas et al., 2010; Zhang et al., 2020). Significantly lower values of $n$-$3$ PUFAs were observed in S. maena and P. incisus, and they had lower DHA proportions.

MUFA and EPA significantly increased in June and, conversely, the remaining PUFA (especially DHA) lowered in most species, except in B. boops and S. maena, which displayed an inverse trend. Interestingly, the SFA fraction decreased in June only in Sparidae species.

Several researchers have reported an increase in PUFA and a decrease in MUFA and SFAs in fish sampled in winter versus summer (Celik, 2008; Batičić et al., 2009; Batičić et al., 2011; Suárez et al., 2015) owing to the higher degree of FA unsaturation needed to preserve fluidity of membranes at low temperature (Henderson & Tocher, 1987). The changes observed in the present study can be explained by lower feed intake in winter, which causes lipid reserve depletion. Thus both SFAs and MUFA are catabolized to a greater extent, which could be why an increase in the PUFA fraction was seen (Shirai et al., 2002; Orban et al., 2011).

El Oudiani et al. (2019) have reported high MUFA levels in autumn for S. scombrus, although Soriguer et al. (1997) found an inverse trend for the same species (high MUFA levels in winter). Such differences may be due to different fish physiological states or changes in diet composition during distinct seasons.

DHA is an essential FA located in the phospholipids of cell membranes and is preferentially preserved rather than metabolized for energy production (Bell et al., 1986). Therefore, when DHA amounts do not suffice for structural needs in winter, DHA synthesis from EPA takes place and leads to the observed low EPA levels in January. The high MUFA and EPA and lower DHA and $n$-$6$ PUFAs percentages observed in the June sampling could confirm this hypothesis.

**Quality index**

The $n$-$3$/n-$6$ ratio is a good marker for assessing the nutritional value of any seafood, and high values indicate good quality lipids: $n$-$3$ PUFA perform anti-inflammatory and anti-aggregatory activities (Calder et al., 2017). Our results fell within the established range from 3.3 to 14.4 (Henderson & Tocher, 1987), and T. mediterraneus and T. draco stood out (7.4 and 6.9). The lowest values were found in the species with high MUFA and low $n$-$3$ PUFA levels: 3.7 in S. maena and 3.3 in P. incisus. P. pagrus and P. acarne obtained high AA percentages and their $n$-$3$/$n$-$6$ ratios were also relatively low (3.4 and 3.9). Values above 3.0 were found in most marine fish species (Celik, 2008). Values higher than 3.5 have been reported to help to lower cholesterol levels in blood and to improve the plasma lipid profile (Morales-Medina et al., 2015).

The PUFA/SFA ratio is another index normally used to evaluate lipid quality, and values above 0.45 are considered positive in human diet given their potential to lower serum cholesterol (Zhang et al., 2020). In the January sampling, the PUFA/SFA ratio ranged between 0.80 in S. maena and 1.59 in S. smaris, and values lowered in the June sampling for all species. All the discarded species included in the present study obtained PUFA/SFA ratios above the recommended value, except P. acarne (0.33) in the June sampling. This finding agrees with results of Özogul et al., (2009) for several fish species from the Mediterranean Sea.

Atherogenic (AI) and thrombogenic (TI) indices are determined by the relative contents of several FAs and indicate the capacity of the lipid fraction to protect against aggression in the endothelium of blood vessels (atheroma formation), and to produce thrombosis or embolism, respectively. Their determinations are based on the functional effects of FAs on cholesterol metabolism. The most important hypercholesterolemic SFAs are C14:0 and C16:0, while hypcholesterolemic ones are C18:1n-9, C18:1n-7 and PUFAs. High values for these indices indicate an increased risk of platelet aggregation and of thrombus and atheroma formation. All values were favorable (<1) and, therefore, the lipids of the studied species can be considered healthy (Morales-Medina et al., 2015). The highest AI values were 0.56 (T. mediterraneus and S. maena) in the January sampling and 0.66 (T. trachurus) in June, whereas the higher value for TI was 0.42 (P. incisus) in January, and all values were lower in June. These values fell within the range indicated by other authors for Mediterranean fish (ÖZogul et al., 2009; Orban et al., 2011; Morales-Medina et al., 2015) as promising marine food to prevent cardiovascular disorders.

The amount of different FAs (g of FA/100 g tissue) was one of the most relevant pieces of information that this study provides because it indicates the FA concentration in the fish body. The largest $n$-$3$ PUFAs amounts in January were for P. incisus, C. lucerna and T. draco (1.36, 1.67 and 2.04 g/100 g, respectively). In June, significantly larger quantities of $n$-$3$ PUFAs were observed in P. acarne (3.89 g/100 g). The lowest values were obtained in the winter sampling for Sparidae fish (0.8-1.0 g/100 g). Similar values have been reported for fish in the Mediterranean Sea (Loukas et al., 2010; Morales-Medina et al., 2015) and in the South Pacific (Rincón-Cervera et al., 2020). These findings indicate that, despite seasonal fluctuations, discarded fish is a raw source of bioactive FA, such as EPA and DHA.
Conclusion

High FA contents were found in *C. lucerna*, *T. draco* and *P. incisus*, which also had high body weight values. This fact could not be related to changes in the reproductive cycle because these individuals were caught in January, outside their spawning season. The FA content increased in the summer sampling compared to winter in most studied species, especially *P. acarne* and *T. trachurus*, which, apart from a significantly heavier body weight, could be due to increased food availability.

The n-3 PUFA percentages were high (between 35% and 46% of total FAs) in most studied species, and EPA, and specially DHA, were the most valuable PUFAs found. However, significantly low n-3 PUFA values were observed in *S. maena* and *P. incisus*. In summer, a significant increase in MUFA and EPA, and a decrease in PUFA and DHA percentages, took place in most species. The capture season influenced the total n-3 PUFA fraction, with the highest values in winter for *P. incisus* (1.36 g/100 g), *C. lucerna* (1.67 g/100 g) and *T. draco* (2.04 g/100 g), and in summer for *P. acarne* (3.89 g/100 g).

Despite seasonal fluctuations, the discarded fish here-in analyzed can be considered not only healthy for humans according to their FA composition, but also a raw source for the production of edible oils rich in EPA and DHA.

References

Arai, T., Amalina, R., Bachok, Z., 2015. Fatty acid composition indicating diverse habitat use in coral reef fishes in the Malaysian South China Sea. *Biological Research*, 48, 1-5.

Aydn, M., Tufan, B., Seygili, H., Köse, S., 2013. Seasonal changes in proximate composition and fatty acid profile of pufferfish (*Lagocephalus sceleratus Gmelin*, 1789) from the Mediterranean Sea of Turkey. *Journal of Aquatic Food Product Technology*, 22 (2), 178-191.

Batličić, L., Varljen, N., Butorac, M.Z., Kapovic M., Varljen, J., 2009. Potential value of hepatic lipids from white sea bream (*Diplodus sargus*, L.) as a good source of biomedical components, seasonal variations. *Food Technology Biotechnology*, 47 (3), 260-268.

Batličić, L., Varljen, N., Kapovic, M., Varljen, J., 2011. Fish lipids as a source of healthy components: Fatty acids from Mediterranean fish. Biomedical Engineering, Trends, Research and Technologies, Malgorzata Anna Komorowska and Sylwia Olszynska-Janus, IntechOpen.

Bell, M.V., Henderson, R.J., Sargent, J.R., 1986. The role of polysaturated fatty acids in fish. *Comparative Biochemistry and Physiology*, 83 (4), 711-719.

Blanco, M., Dominguez-Timon, F., Pérez-Martín, R.I., Fraguas, J., Ramos-Ariza, P. et al., 2018. Valorization of recurrently discarded fish species in trawler fisheries in North-West Spain. *Journal of Food Science and Technology*, 55 (11), 4477-4484.

Calder, P.C., Bosco, N., Bourdet-Sicard, R., Capuron, L., Delzenne, N. et al., 2017. Health relevance of the modification of low grade inflammation in ageing (inflammageing) and the role of nutrition. *Aging Research Reviews*, 40, 95-119.

Carbonell, A., García, T., González, M., Álvarez-Berastegui, D., Mallo, S. et al., 2018. Modelling trawling discards of the Alboran fisheries in the Mediterranean Sea. *Regional Studies in Marine Science*, 23, 73-86.

Celik, M., 2008. Seasonal changes in the proximate chemical compositions and fatty acids of chub mackerel (*Scomber japonicus*) and horse mackerel (*Trachurus trachurus*) from the northeastern Mediterranean Sea. *International Journal of Food Science & Technology*, 43, 933-938.

El Oudiani, S., Chetoui, I., Darej, C., Moujahed, N., 2019. Sex and seasonal variation in proximate composition and fatty acid profile of *Scomber scombrus* (L. 1758) fillets from the Middle East Coast of Tunisia. *Grasas y Aceites*, 70 (1), e285.

El-Serafy, S., El-Gammal, F.I., Mehanna, S.F., Abdel-Hamid, N.H., El-Sayed Farrag, F.E., 2015. Age, growth and reproduction of the tub gurnard, *Chelidonichthys lucerna* (Linnaeus, 1758) from the Egyptian Mediterranean waters off, Alexandria. *International Journal of Fisheries and Aquatic Sciences*, 4 (1), 13-20.

Falch, E., Rustad, T., Aursand, M., 2006a. By-products from gadiform species as raw material for production of marine lipids as ingredients in food or feed. *Process Biochemistry*, 41, 666-674.

Falch, E., Rustad, T., Jonsdottir, R., Shaw, N.B., Dumay, J. P. et al., 2006b. Geographical and seasonal differences in lipid composition and relative weight of by-products from Gadidae species. *Journal of Food Composition and Analysis*. 19 (6-7), 727-736.

FAO, 2018. The State of Mediterranean and Black Sea Fisheries. General Fisheries Commission for the Mediterranean. Rome. 172 pp.

Fehri-Bedoui, R., Gharbi, H., 2008. Sex-ratio, reproduction and feeding habits of *Pomadasys incisus* (Haemulidae) in the Gulf of Tunis (Tunisia). *Acta Adriatica*, 49 (1), 5-19.

García, T., Baez, J.C., Baro, J., García, A., Giráldez, A., Macias, D. 2012. La pesca en el mar de Alborán. Technical Report.

Garcia Mesa, S., Suárez, M.D., Rincón-Cervera, M.A., Guíl-Guerrero, J.L., González, G. et al., 2014. Time course of muscle fatty acid composition of cultured meagre (*Argyrosomus regius*) during the first sixteen months of a cage culture. *Grasas y Aceites*, 65 (1), e006.

García-Moreno, P.J., Pérez-Gálvez, R., Espejo-Carpio, F.J., Muñio, M.M., Guadix, A. et al. 2013. Lipid characterization and properties of protein hydrolysates obtained from discarded Mediterranean fish species. *Journal of the Science of Food and Agriculture*, 93, 3777-3784.

Gilman, E., Perez Roda, A., Huntington, T., Kennelly, S.J., Suuronen, P. et al. 2020. Benchmarking global fisheries discards. *Scientific Reports*, 10, 14017.

Guil-Guerrero, J.L., Rincón-Cervera, M.A., Gómez-Mercado, F., Ramos-Bueno, R.P., Venegas-Venegas, E., 2013. New seed oils of *Boraginaceae* rich in stearidonic and γ-linolenic acids from the Maghreb region. *Journal of Food Composition and Analysis*, 31 (1), 20-23.

Henderson, R.J., Tocher, D.R., 1987. The lipid composition and biochemistry of freshwater fish. *Progress in Lipid Research*, 26 (4), 281-347.

Kandyliari, A., Mallouchos, A., Papandroulakis, N., Golla, J.P.,
Lam, T.T. et al., 2020. Nutrient composition and fatty acid and protein profiles of selected fish by-products. *Foods*, 9 (2), 190.

Kolakowska, A., Olley, J., Dunstan, G.A., 2003. Fish lipids. 228-223. In: *Chemical and functional properties of food lipids*. Sikorski, Z.E., Kolakowska, A. (Eds.), CRC Press Florida.

Loukas, V., Dimizas, C., Sinanglou, V.J., Miniadis-Meimaroglou, S., 2010. EPA, DHA, cholesterol and phospholipid content in *Pagrus pagrus* (cultured and wild). *Trachinus draco* and *Trigla lyra* from Mediterranean Sea. *Chemistry and Physics of Lipids*, 163 (3), 292-299.

Moraes-Medina, R., García-Moreno, P.J, Pérez-Gálvez, R., Muñio, M., Guadix, A. et al., 2015. Seasonal variations in the regiodistribution of oil extracted from small-spotted catshark and bogue. *Food & Function*, 6 (8), 2646-52.

Nascimento, V.L.V., Bermúdez, V.M.S., Oliveira, A.L.L., Kleinberg, M.N., Ribeiro, R.T.M. et al., 2015. Characterization of a hydrolyzed oil obtained from fish waste for nutraceutical application. *Food Science and Technology*, 35 (2), 321-325.

Orban, E., Di Lena, G., Nevigato, T., Masi, M., Casini, I. et al., 2011. Proximate, unsaponifiable lipid and fatty acid composition of bogue (Boops boops) and horse mackerel (Trachurus trachurus) from the Italian trawl fishery. *Journal of Food Composition and Analysis*, 24 (8), 1110-1116.

Ordines, F., Fariolos, M., Leonart, J., Guijarro, B., Quetglas, A. et al., 2014. Biology and population dynamics of by-catch fish species of the bottom trawl fishery in the western Mediterranean. *Mediterranean Marine Science*, 15 (3), 613-625.

Özdemir, S., Özsandıkç, U., Büyükdeveci, F. 2019. A new maximum length with length–weight relationship of tub gurnard (Chelidonichthys lucerna Linnaeus, 1758) from Central Black Sea coasts of Turkey. *Marine Science and Technology Bulletin*, 8 (2), 85-91.

Özogul, Y., Özogul, F., Çiçek, E., Polat, A., Kuley, E., 2009. Fat content and fatty acid compositions of 34 marine water fish species from the Mediterranean Sea. *International Journal of Food Sciences and Nutrition*, 60 (6), 464-475.

Ozyilmaz, A., 2016. Investigation of proximate and fatty acid compositions of Champsodon nudivittis, a discard fish, from Northeastern Mediterranean. *Chemistry Research Journal*, 1 (4), 117-121.

Pajuelo, J.G., Lorenzo, J.M., Greigore, M., 2003. Age and growth of the bastard grunt ( Pomadasys incisus: Haemulidae) inhabiting the Canarian archipelago, Northwest Africa. *Fisheries Bulletin*, 101 (4), 851-859.

Portillo Strempel, S.A., Baro, D.J., Mancera, R.J.M., Herrera, C.E., 2008. Distribución espacial de Trachinus draco (Linnaeus, 1758) (Perciforme, Trachinidae) en el norte del Mar de Alborán (España). *Zoologica Baetica*, 19, 3-14.

Rincón Cervera, M.A., Venegas Venegas, E., Ramos Bueno, R.P., Suárez Medina, M.D., Guil-Guerrero, J.L., 2014. Docosahexaenoic acid purification from fish processing industry by-products. *European Journal of Lipid Science and Technology*, 117 (5), 724-729.

Rincón-Cervera, M.A., González-Barriga, V., Romero, J., Rojas, R., López-Arana, S., 2020. Quantification and distribution of omega-3 fatty acids in South Pacific fish and shellfish species. *Foods*, 9 (2), 233.

Rustad, T., Storme, I., Slizyte, R., 2011. Possibilities for the utilization of marine byproducts. *International Journal of Food Science & Technology*, 46 (10), 2001-2014.

Sánchez, P., Demestre, M., Martín, P., 2004. Characterization of the discards generated by bottom trawling in the northwestern Mediterranean. *Fisheries Research*, 67 (1), 71-80.

Shirai, N., Terayama, M., Takeda, H., 2002. Effect of season on the fatty acid composition and free amino acid content of the sardine Sardinops melanolentis. *Comparative Biochemistry and Physiology. Part B: Biochemistry & Molecular Biology*, 131 (3), 387-93.

Simopoulos, A.P., 2004. Omega-6/omega-3 essential fatty acid ratio and chronic diseases. *Food Reviews International*, 20 (1), 77-90.

Sorguer, F., Serna, S., Valverde, E., Hernando, J., Martín-Reyes, A. et al., 1997. Lipid, protein, and calorie content of different Atlantic and Mediterranean fish, shellfish, and molluscs commonly eaten in the south of Spain. *European Journal of Epidemiology*, 13 (4), 451-463.

Suárez, M.D., González, M.J. Sáez, M.I., Martinez, T.F., Guil-Guerrero, J.L., 2015. Seasonal changes of proximate composition and fatty acids of farmed dusky grouper (Epinephelus marginatus Lowe, 1834). *International Journal of Food Science & Technology*, 50 (8), 1823-1830.

Tsagarakis, K., Palialexis, A., Vassilopoulou, V., 2014. Mediterranean fishery discards: review of the existing knowledge. *ICES Journal of Marine Science*, 71 (5), 1219-1234.

Tschikras, A.C., Stergiou, K.I. 2014. Size at maturity of Mediterranean marine fishes. *Reviews in Fish Biology and Fisheries*, 24, 219-268.

Ulbricht, T.L., Southgate, D.A., 1991. Coronary heart disease: seven dietary factors. *Lancet*, 338(8773), 985-992.

Urra, J., García, T., Gallardo-Roldán, H., León, E., Lozano, M., et al. 2017. Discard analysis and damage assessment in the wedge clam mechanized dredging fisheries of the northern Alboran Sea (W Mediterranean Sea). *Fisheries Research*, 187, 58-67.

Yildiz, M., Sener, E., Timur, M., 2006. The effects of seasons and different feeds on fatty acid composition in fillets of cultured gilthead sea bream (Sparus aurata L.) and European sea bass (Dicentrarchus labrax L.) in Turkey. *Turkish Journal of Veterinary and Animal Sciences*, 30 (1), 133-41.

Zhang, X., Ning, X., He, X., Sun, X., Yu, X. et al., 2020. Fatty acid composition analyses of commercially important fish species from the Pearl River Estuary, China. *PLoS ONE*, 15(1), e0228276.

**Supplementary data**

The following supplementary information is available online for the article:

**Table S1.** Fresh fish commercially available in Almeria from January 01 to December 31, 2018.