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Fishery essentiality: A short-term decision-making method based on economic viability as a tool to understand and manage data-limited small-scale fisheries

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ABSTRACT

Small-scale fisheries (SSFs), usually overlooked and marginalized in policy processes, play an important role in contributing to food security, nutrition, livelihoods, and local and national economies. As conventional fisheries assessment is not valid for SSFs, this study puts forward several mathematical indices to numerically qualify the state of certain SSFs. We have developed a new concept of 'essentiality', which measures the relative importance of certain species from an economic perspective. In the framework of fishery essentiality, SSFs boats are conceptually replaced by Artisanal Fishing Units. The time dedicated to the capture of a species, the number of units that fish it, and the economic yield obtained from the sale of the catch: Frequency, Fleet Recruiting and Income, define essentiality. We have set out an overall index of essential capacity for the whole fishery. Estimating the essentiality of a fishery allows us to comparatively characterize different fishing communities, and the data-limited SSF manager has the option of introducing management measures to change the behaviour of the fishery and move towards a situation of greater essentiality, and therefore, of greater economic viability. This in turn leads to a reduction in the pressure that is focused on a limited number of specific fishing resources. The essentiality of a fishery is a plausible alternative method of assessment and management of a fishery to the traditional evaluation methods used for industrial fisheries.

1. Introduction

Small-scale fisheries (SSFs) play an important role in contributing to food security, nutrition, livelihoods, and local and national economies (FAO, 2017). Despite the name, SSFs are by no means "small." On the contrary, SSFs are much larger than previously thought and appear to have an outsized impact on human health and nutrition, poverty alleviation, jobs, and the structure of seafood markets (Jentoft et al., 2017; Smith and Basurto, 2018). In 2010 there were 34.5 million people engaged directly in SSFs, and the livelihoods of about 357 million people were directly related to SSFs (FAO, 2012). The catch per tonne of fuel consumed in small-scale fishing is 4–5 times higher than for large-scale fishing, and the number of fishers employed per $ 1 million investment in fishing vessels is at least 100 times greater in small-scale than in large-scale fisheries (Pauly, 1997, 2006; Chuenpagdee et al., 2006). However, the nature and importance of these contributions to food and nutritional security, livelihoods and sustainability remain inadequately recognized in development, food, environmental and fisheries policies (Short et al., 2021; Bennett et al., 2021; FAO, 2017).

In the EU, fleets are dominated by SSF vessels, representing about 80% of all fishing vessels and 40% of the total employment in the fishing sector (OECD, 2016). The European Commission has developed a so-called 'Blue Growth (BG) Strategy' as part of the maritime dimension of Europe's 2020 strategy for smart, sustainable, and inclusive growth. The seas and oceans are considered to provide great potential for innovation and growth. Fisheries, being a traditional maritime activity, are not integrated in the BG strategy, presumably because they are perceived as having limited potential for growth (Stobberup et al., 2017). The modern history of the European fishing sector has been deeply affected by public policies: nation states have influenced the development of fisheries through subsidies, promoting legislation, or restricting specific fishing strategies, as well as market interventions, amongst others. Given the poor state of many fish stocks in European waters, some measures, such as funding for the scrapping of vessels,

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have been taken to supposedly diminish the capacity of European fleets. However, it appears that efforts to limit the capacity of EU fleets have had meagre results at best (Pascual-Fernández et al., 2020; Villasante, 2010). Even though it is difficult to estimate the impacts of small-scale fleets on these depleted stocks, SSFs have been affected by the same scrapping policies. This is an illustration of how policies that have been primarily aimed at large-scale fleets have had consequences for fisheries as a whole, including SSFs (Pascual-Fernández et al., 2020).

The literature on fishers' local ecological knowledge shows the importance of considering this knowledge when developing fishery management plans (Torres-Guevara et al., 2016; Dang et al., 2015). Conventional fisheries assessment does not provide an adequate basis for informed management decisions and development planning in the small-scale subsector. Current assessment methods and procedures have failed to maintain legitimacy as they lack conceptual coherence and often neglect to incorporate important aspects of the fishery system (García et al., 2008). One of the challenges in the assessment and management of SSFs is the acquisition of pertinent, reliable, and detailed information, which can generally be time consuming and costly (Salas et al., 2007; Chuenpagdee et al., 2011; Saldaña et al., 2016). Under data-limited conditions, the identification of simple fishery indicators is pertinent as it is useful to assess the impact of different factors, including fishing on marine resources (Garcia et al., 2009; Kim and Zhang, 2011; Saldaña et al., 2016). This becomes relevant in the context of SSFs, where fishers develop adaptive strategies in response to different stressors and to the uncertainty associated with the fishing activity (Salas and Gaertner, 2004; Torres-Guevara et al., 2016; Naranjo-Madrigal et al., 2015). Fluctuations in market demand and the availability of exploited resources due to changing conditions in the market system and climate conditions can lead to variation in the strategies developed by fishers at an operational level (Salas et al., 2004; Tzanatos et al., 2013; Chollett et al., 2014). Fishery managers should facilitate this SSF polyvalence (this is, the capacity of an artisanal fishing unit to apply different fishing strategies, often during the same fishing trip) to encourage distribution of fishing effort among fishery resources, contributing to alleviate the most fished resources from high levels of over-exploitation, especially when dealing with high trophic level vulnerable species.

In this regard, this study should be understood as the starting point for a new approach to SSF management. In the bibliography we have found a distinct lack of contributions to conceptual models of SSFs that take into account the economic importance of caught species (Ojeda Ruiz de la Peña and Ramírez Rodríguez, 2012). We put identify mathematical indices to numerically qualify the state of a SSF, leaving aside the traditional use of concepts such as the resource biomass, the fishing effort, or the maximum sustainable yield. These indices will enable comparisons to be carried out on parameters of versatility, polyvalence, and multi-specificity between fishing periods and/or fishing communities. In this work, we develop with a new concept of 'essentiality', which will be mathematically proven. Moreover, we apply this concept to the Canary Islands to give an illustrative example of the proposed indices. Finally, this mathematical exercise will lead to a diagnosis of the weak points, the potentialities, and the best management options, comparing the strength of different SSFs communities and their fishing strategies, regardless of the social, technological, or biological traits that may influence them.

2. Conceptual model: fishery essentiality and its analytical demonstration

2.1. Essential, fundamental, and complementary species

SSFs discards are usually almost nonexistent, unlike the case of industrial fisheries. However, not all species of fishing interest have the same importance for the stable and profitable maintenance of SSFs. Catch compositions depend on availability, market, and vulnerability to fishing gear. The concept of target species in a SSF is something to consider, but it does not always indicate the importance of the species in question within a general fishing context. The essential characteristics that identify and differentiate a SSF from a certain locality are the result of the fishing intensity of each species caught by that fishery, and that intensity depends on a series of ecological, biological, fishing, and commercial factors. In this study we will analyse fishing and commercial aspects.

Species of fishing interest can be divided into three categories: essential, fundamental, and complementary species. The first two are basic target species for the maintenance of fishing activity; usually consisting of no more than 15 per fishing community and generating around 85% of the economic income from fishing. These species determine local fishing strategies and support the intensity and generation of income from fishing activities. Complementary species are those that are usually landed together with other more important species, or those that, whilst targeted at a given moment, do not make up a significant share of the income derived from fishing. Among the latter are also those with catch volumes that generally contribute very little to annual landings, or those that are caught sporadically and only report several tonnes.

The essential species are those that characterize the fishing strategies of each fishing community, and fleets, fishing gears and fishers' behaviour are conditioned by them. They usually represent between 60% and 70% of the economic income from fishing and often do not exceed half a dozen species. The stability and income generated from fishing is based on these type of resources; that vary according to fleet polyvalence, with an abundance that depends on the state of their habitat and their level of exploitation; and essential because if they are lacking, the fragile balance that regulates seasonality in fishing strategies is broken, leading to an increase of effort towards other species that have already been, or indeed will be fished, throughout the year.

However, the essential species cannot sustain the fishing industry by themselves, not even with the contribution of the complementary ones. They need some fundamental species, whether seasonal or not, that have a similar capacity to essential ones to create and evolve specific fishing strategies that allow the partial or total diversion of effort at certain times of the year. These fundamental species have many similarities with the essential ones, but whether due to their low biomass, lack of seasonality, limited vulnerability, or insufficient commercial income generation, they do not reach the level of importance of the essential ones. The potentiality of these fundamental species to become essential, and the capacity to establish measures that increase their essentiality, are crucial factors when analysing the usefulness of this model.

2.2. Essentiality index: concept

The essentiality index measures the relative importance of a certain species, or group of species, within an SSF. It should not be understood as a measure of effort, or a biological measure. Rather, it is an economic measure characterizing the type of fishing, a qualitative measure of fishing exploitation. The index quantifies income generation and gauges the intensity with which a species is fished, with the greater the income generation, vulnerability to fishing, and availability of the resource, the higher the fishing intensity. This is due to the fact that the typical versatility of SSF fleets always tends to lead to profit-orientated fishing strategies.

Moreover, it is convenient to rethink the concept of the constituent parts that are involved in, and make up the fishing effort. Traditionally, we have paid attention to certain characteristics of the fishing vessel, the number of fishers or, at best, the number of hooks or fishing gears. This, which could be valid for industrial fisheries, is quite inefficient for SSFs and not at all appropriate for the concept of essentiality.

SSFs boats do not always behave as productive units. In fact, boats function as fishing tools that can be exchanged, modified and adapted. Fishers are autonomous agents who freely determine the type and fishing method they want to conduct, and depending on that preference, and the fishing gear they have, they could use one, two, or more boats to achieve their goals. This quality identifies and differentiates SSFs, and determines the degree of versatility, polyvalence, and multi-specificity of the fishing. Thus, we define an Artisanal Fishing Unit (AFU) as the set of boats, fishers and gears that are grouped associatively to carry out various types of fishing. The AFU concept has nothing to do with the definition *Unit of Assessment* or *Unit of Certification* used by the Food Agriculture Agency or Marine Stewardship Council. While these concepts aim to define homogeneous segments of the fishery that are to be assessed and potentially certified, the AFU are brought about by fishers' associative intentions when aiming to improve economic yield. The AFU concept links the decisive action of fishers to the availability and adaptability of fishing boats and gears. AFUs are not entirely independent units, as they are immersed in social, cultural and market relationships that make it feasible or not to develop specific strategies. Essentiality indices may contribute to understanding the variation among fishing communities and consider issues related to the ecosystem and fishing resources and those related to the specific local market conditions. This is a key characteristic of SSFs that needs to be considered when analysing the fishing strategies and resource extraction of a community, and needs to be integrated into the indices being developed. In large scale fisheries the strong links to world markets make this linkage to local circumstances less relevant.

There are three factors of utmost importance in understanding or quantifying the fishing intensity that is exerted on a species: the time dedicated to the capture of a species, the number of units that fish it, and the economic yield obtained from the sale of the catch: Frequency, Fleet Recruiting and Income.

- **Frequency** (F) is the number of days in which a certain species is fished, divided by the total number of days of fishing activity of the entire fleet and all species. This period can be limited to months, quarters, semesters, or years, depending on the type of study. As a general rule, it is for a year, since this covers the set of seasonal species. Thus, taking the period of one year, the total number of fishing days cannot exceed 365 or 366. The mathematical result will be an index that ranges from 0 to 1. It can refer to a species or a group of species, and the days in which an attempt at fishing is made but not carried out are not counted. Failed attempts should not be taken into consideration in Frequency calculations because the essentiality index is not an estimation of effort, but a measure of relative importance in the total fishing result obtained. However, this value does not detect seasonality; an aspect yet to be solved with some measure of dispersion, since from the point of view of essentiality a seasonal species has a different value than a non-seasonal one.
- **Fleet Recruiting** (R) is the number of AFUs that fish a species, divided by the total number of AFUs. The result will be an index that ranges from 0 to 1. The R of a certain species includes AFUs with income rates for the species in question greater than a certain threshold (5 or 10%) of that AFU's total earnings; so, we are adding an essentiality character to this parameter. The paradox could be that an AFU with higher landings is discarded from the R count compared to another with lower landings. Once again, we discard the effort in favour of the relative importance that a species has on the set of catches of each of the AFUs. Thus, species that are not fished in large quantities, but are usually fished by a high number of AFUs, would not be considered, if they do not exceed the income rate threshold.
- **Income** (P) could be calculated by dividing the economic value obtained from the sale of one species by the total income of all species. However, in many multi-species fisheries it is common for none of the species to exceed 40% of the earnings, which leads to P values very close to 0. The combination of these absolute values with those of frequency and fleet recruiting would produce very low essentiality figures. A preferred approach is to estimate relative incomes, dividing the income generated by each species by the income obtained from the species that generate the highest income levels. This new income index, denoted as p (p = P / P_max), ranges from 0 to 1. In order to quantify the value that a given species has for fishers, which is the fundamental goal of the model, the biological parameter of biomass is left out.

Thus, the parameters that numerically determine the importance of a species can be calculated from F, R and p. F quantifies the presence of the resource and the intensity with which it is fished, contributing a component of biological abundance to the indices. R measures the ability of the fleet to incorporate a certain fishing strategy, and p measures economic value as a fundamental element that leads fishers to prioritize the exploitation of resources that generate the highest income levels, regardless of their biomass.

2.3. Essentiality index: analytical demonstration

With F, R and p defined, the next step is to calculate an essentiality index that combines these three parameters. We start from the premise that F and R have a similar behaviour, indicating an increase in the fishing intensity of a certain species as their values approach 1. The higher the F and R values, the greater the essentiality of a species since it implies a sustained catch over time and determines the fishing strategies of the majority of AFUs.

Analytically, it can be observed that neither the sum of the F of the species, nor the sum of their Rs, is 1. The reason is that more than one species can be caught on the same fishing day and that more than one AFU can fish it. Grouping these two parameters into a new variable called fishing intensity (i) facilitates the formulation necessary to calculate the essentiality index. Even though precedents such as Ojeda Ruiz de la Peña and Ramírez Rodríguez (2012) assign the same weight to the several parameters influencing fishery importance, this new variable could not be the product of the two parameters. This is because quantifying in the same way a species fished x days by y AFUs with another fished y days by x AFUs would be a mistake. Actually, these two cases should be assessed in different ways.

To address this problem, we define fishing intensity as the volume of a cone, where R is the radius and F is the height.

$$i = \frac{\pi \quad R^2 F}{3}$$

At certain frequency levels, frequency increases no longer have an effect on essentiality, because the essential capacity of a multispecies fishery increases when more essential species exist in the fishery and diversification efforts between these species is favoured. As a result, it is important that the numerical frequency index reaches essentiality when it comes to seasonal fisheries with greater than 90 days of fishing (frequency 0.24, fleet recruiting 0.7). Interpreting this behaviour as the volume of a cone is a logical way of unifying two variables with different specific gravity into a single formula that connects them. Considering that the increase in the radius at the base of the cone means a much larger rise in volume than an increase in height in the last section of the cone, we can assign the number of AFUs to the radius and the frequency to the height. So, R is given more weight than F under the premise that, for example, the essentiality of a species fished by 40% of the AFUs and 60% of the fishing days is lower than the one of a species captured on 40% of the days and by 60% of the AFUs. In addition, this formulation implies that at low F and R values, the fishing intensity is minimal, while from values above 0.5 the growth is exponential.

At a fixed level of fleet recruiting, frequency increases produce linear rises in intensity (the volume of the cone). However, at a fixed level of frequency, an increase in fleet recruiting generates exponential rises in intensity. When analysing the possible results of the fishing intensity (Table 1) we see that 43% of the values are less than 0.1, 60% less than 0.2, and so on (as represented in the percentage column in the table included in Fig. 1). If these percentages are considered to be no more

Table 1
Fishing intensity (i) estimation according to Frequency (F) and Fleet Recruiting (R).

Fleet Recruiting (R) \ Frequency (F)	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
0.1	0.0010	0.0021	0.0031	0.0042	0.0052	0.0063	0.0073	0.0084	0.0094	0.0105
0.2	0.0042	0.0084	0.0126	0.0168	0.0209	0.0251	0.0293	0.0335	0.0377	0.0419
0.3	0.0094	0.0188	0.0283	0.0377	0.0471	0.0565	0.0660	0.0754	0.0848	0.0942
0.4	0.0168	0.0335	0.0503	0.0670	0.0838	0.1005	0.1173	0.1340	0.1508	0.1676
0.5	0.0262	0.0524	0.0785	0.1047	0.1309	0.1571	0.1833	0.2094	0.2356	0.2618
0.6	0.0377	0.0754	0.1131	0.1508	0.1885	0.2262	0.2639	0.3016	0.3393	0.3770
0.7	0.0513	0.1026	0.1539	0.2053	0.2566	0.3079	0.3592	0.4105	0.4618	0.5131
0.8	0.0670	0.1340	0.2011	0.2681	0.3351	0.4021	0.4691	0.5362	0.6032	0.6702
0.9	0.0848	0.1696	0.2545	0.3393	0.4241	0.5089	0.5938	0.6786	0.7634	0.8482
1	0.1047	0.2094	0.3142	0.4189	0.5236	0.6283	0.7330	0.8378	0.9425	1.0472

i	%	∃i
0.01	12	0.11
0.1	43	0.47
0.2	60	0.62
0.3	71	0.71
0.4	79	0.78
0.5	85	0.84
0.6	90	0.88
0.7	94	0.92
0.8	96	0.95
0.9	98	0.98
1	99	1

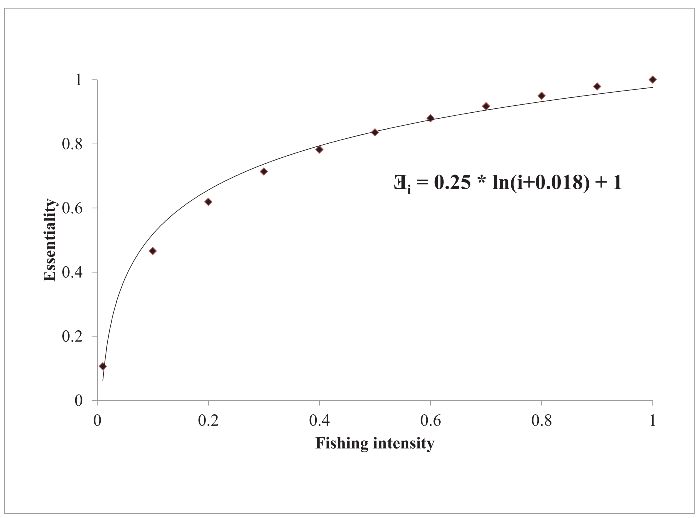

Fig. 1. Graphical representation of the expected essentiality index based on the fishing intensity index.

than a measure of essentiality, several results can be highlighted. Firstly, when R or F exceed 50%, *i* is greater than 0.1. At F values of 10%, it is only possible to obtain *i* values greater than 0.1 when the R is equal to 1. At R values of 40% we will only obtain *i* values greater than 0.1 when the F values reach 60%. From these mid F and R values on, a typical logarithmic growth is observed.

When representing the obtained percentage values against the fishing intensity, a very evident logarithmic behaviour is observed, which reinforces the original idea that it behaves as if it were the volume of an inverted cone, where an increase in the height and radius cause the magnitude of the volume to increase logarithmically. Fitting these percentage values to a graphical representation (Fig. 1) and to a logarithmic curve, essentiality estimations due to the fishing intensity ($\exists_i$) are obtained.

$$\exists_i = 0.25 \times \ln(i + 0.018) + 1$$

The $\exists_i$ values are decimal and are rounded to two decimal places, with a logarithmic formula where *i* values greater than 0.118 (F and R values greater than 50%) produce a $\exists_i$ greater than or equal to 0.5. In the formula, 0.018 is added to the *i* value to assure values of $\exists_i$ equal to 0 when *i* values (with two decimal places) approach 0.

Similar calculations for the Income rate index (*p*) have to be performed. In this case, it is assumed that *p* rates greater than 0.3 can be considered essential. The selection of this high-income threshold for considering a species as essential is due to the fact that, in SSFs, the income generation of a species rarely remains constant throughout an annual period. Typically, there are peaks of catches in certain months of the year and more or less prolonged absences depending on seasonality and/or occasional overexploitation of the species. In these cases, fishing strategies shift to other species that generate less or equal income, but that suddenly become fundamental species for the global maintenance of the fisheries. Quantifying the extent to which a species of this type goes from being considered fundamental to essential is somewhat complex, but necessary.

A simplified example of an annual fishery is represented in Table 2. In this case, of the caught species, species A is generating the highest income levels, even though it is not the one that contributes the most landings, nor is it the one with the highest price. It can be clearly seen that income generation depends on the landings and, to a greater extent, on price. From the landings point of view, a species with the same price

Table 2
Illustrative and simplified example of an SSF. Complementary species are excluded.

	Kg	Price	Income	p	$\exists_p$
species A	15,000	10	150,000	1.00	1.00
species B	120,000	1	120,000	0.80	0.87
species C	9300	5	47,000	0.31	0.50
species D	6500	6	39,000	0.26	0.45
species E	2500	12	30,000	0.20	0.38

as A has a p value higher than 0.31 when landings exceed 4650 kg. Species C exceeds the same p value with 9300 kg because its price is just half that of species A.

There will always be one or more species with $p = 1$. And analytically if the species generating the most income had the same income generation every month of the year, it would have an income rate of 0.08334 per month. Thus, if the exploitation of the resource were evenly distributed throughout the year, it would take 3.72 months to achieve an income rate of 0.31. In other words, any landed species exceeding a p value of 0.31 brings about a level of essentiality to the fishery that would be the equivalent of fishing the highest income generating species of that fishery for over three months. Therefore, whether seasonal or not, there will be species that are essential as a result of their income generation. These species are strategic for the efficient exploitation of the fishery.

Considering the aforementioned premise, we can state that as $p \to 0$, the essentiality value ($\exists_p$) does likewise. When $p = 1$, $\exists_p = 1$. Finally, when $p = 0.31$, $\exists_p = 0.5$. In conclusion, by developing a mathematical approach similar to that already carried out for fishing intensity, the results can be adjusted to a potential curve as shown in the table included in Fig. 2, where the $\exists_p$ values are equal to p values to the power of 0.6.

$$\exists_p = p^{0.6}$$

Once both essentiality components (one depending on i, the other on p) have been estimated, these two indexes need to be grouped into a single mathematical formula. If it is assumed that the best predictable result for the essentiality index is the mean of the two aforementioned values, the following mathematical formula is obtained:

$$\exists_t^{sp} = \frac{p^{0.6} + 0.25 * \ln(i + 0.018) + 1}{2}$$

where $\exists$ is the essentiality index of a species, or a determined group of species, for a period of time t; i is the fishing intensity obtained by multiplying π by the fleet recruiting squared and by the frequency, and then dividing by 3: $i = (\pi R^2 F)/3$; and p is the income rate index ($p = P / P\_max$).

Thus, when $\exists \geq 0.5$, we can say that the species is essential; for $\exists \geq 0.3$ and < 0.5, the species is categorized as fundamental and $\exists$ values below 0.3 correspond to complementary species.

p	∃p
0,001	0,02
0,1	0,25
0,2	0,38
0,3	0,49
0,4	0,58
0,5	0,66
0,6	0,74
0,7	0,81
0,8	0,87
0,9	0,94
1	1

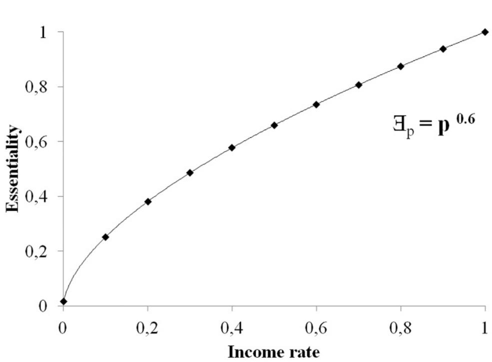

Fig. 2. Graphical representation of the expected essentiality index based on the income index.

2.4. Essential capacity concept: $C_\exists$

In the previous section the concept of essentiality was explained and a method to quantify it was developed. However, the essentiality index $\exists$ applies to individual species, or groups of species, but we are still lacking an overall index that quantifies the essentiality of a whole given fishing community or fishery.

The essential capacity $C_\exists$ combines the total of the essential indices of the species fished at a specific fishery. It is obtained as a weighted sum of essentiality indices, where indices greater than, or equal to 0.5 have a weight of 100, those between 0.3 and 0.5 have a weight of 50, and the remainder have a weight of 1. This weighting gives priority to essential and fundamental species, as fishing grounds with a greater number of these species will support more polyvalent, versatile and, therefore, sustainable fisheries. We look for a numerical value closely representing the number of essential species, and that is also able to detect substantial variation when fundamental species are added. Therefore, on a three-digit scale, the digit of a hundred is determined, to a greater extent, by the number of essential species, and the digit of ten by that of the fundamental species.

$$C_\exists = \sum_{\exists \geq 0.5} \exists * 100 + \sum_{0.5 > \exists \geq 0.3} \exists * 50 + \sum_{\exists < 0.3} \exists$$

$C_\exists > 200$ are typical of fishing communities with two or more essential species and two or more fundamental species. To give an example, if the $C_\exists$ values are 312 and 230, the first has a greater polyvalence and versatility capacity than the second.

$C_\exists$ will allow managers to assess the effectiveness of measures that have been implemented with the aim of increasing fishing essentiality, since by testing the annual trend of $C_\exists$, the negative or positive effects of fishery management measures can be determined.

2.5. Essential potentiality concept: $P_\exists$

$P_\exists$ measures how the essentiality of a given fishery is spread among the 10 most significant species. Essential species don't contribute to $P_\exists$, while the rest of the top 10 species contribution is the result of the difference between 0.5 and its $\exists$ index.

$$\boldsymbol{P_\exists} = \sum_{\exists \geq 0.5} \mathbf{0} + \sum_{\exists < 0.5} \exists - \mathbf{0.5}$$

Its value, always negative, indicates how close to perfect essentiality the essential indices of the 10 most significant species are as a whole. The closer to zero $P_\exists$ is, the closer to that maximum of essentiality the fishery is. This is therefore a clear indicator that allows managers to quantify variations in the essentiality of a fishery where there have been no changes in the number of essential and fundamental species.

3. Essentiality put in practice: some illustrative examples from the Canary Islands

The Canary Islands SSF comprises the vast majority of the professional fishing fleet. It is a fleet with small boats, passive gears, it is polyvalent, and is aimed at multiple species. It is not very high tech, most of its activity is inshore with little energy and capital input. It is seasonal, and landings are sold locally, sustaining local economies, with individual or community ownership, supporting social and cultural values. This SSF exhibits 12 out of the 17 SSF features described by Gibson and Sumaila (2017) in its British Columbia SSF description. A summary of the figures for the 3 examples is presented in Table 3.

3.1. Playa Blanca (S Lanzarote)

Playa Blanca is a small fishers' organization (*Cofradía* in Spanish)

Table 3
Fleet, species, fishing gears and essentiality figures for the 3 case studies during 2019. Top10sp = The 10 most essential species, $C_\exists$ = Essential capacity, $P_\exists$ = Essential potentiality.

Fishing community->	Playa Blanca	Gran Tarajal	La Restinga
Number of AFU	20	43	28
Gross tonnage[1]	3.02	3.50	2.50
Length (m)[1]	8.15	8.58	7.51
Horse power (hp)[1]	48.85	43.05	33.90
Fishing days[1]	80	41	116
Landing (kg)[1]	5900	6300	13,000
Income (€)[1]	31,650	35,350	37,350
Number of landed species	74	70	57
Total landings (kg)	118,000	271,000	375,500
Top10sp contribution to total landings (%)	72	81	92
Total income (€)	633,000	1,520,000	1,000,000
Top10sp contribution to total income (%)	76	81	86
Fishing days	300	263	361
Number of essential species	6	2	3
Number of fundamental species	3	1	5
$C_\exists$	499	139	312
$P_\exists$	-0.45	-2.21	-1.11

Table 4
Taxa categories codes for Fig. 4.

Taxa Code	Taxa category
PPAG	*Pagrus pagrus*
PDEN	*Pseudocaranx dentex*
DGIB	*Dentex gibbosus*
SCRE	*Sparisoma cretense*
EMAR	*Epinephelus marginatus*
SCAN	*Spondyliosoma cantharus*
SERR	*Serranus* spp
PAUR	*Pagrus auriga*
BCAP	*Balistes capriscus*
DSAR	*Diplodus sargus*
TTHY	*Thunnus thynnus*
BERY	*Beryx* spp
MULL	*Mullus* spp
MMER	*Merluccius merluccius*
TALA	*Thunnus alalunga*
ASOL	*Acanthocybium solandri*
KPEL	*Katsuwonus pelamis*
TOBE	*Thunnus obesus*
PLES	*Plesionika* spp
MAUG	*Muraena augusti*

located on the Southern coast of Lanzarote, on the north-eastern side of the archipelago (Fig. 3). Landings for 2019 from the First Sale Spot allow a certain description of the fishery. Twenty AFUs have been identified, with a mean gross tonnage (GT), length (m) and horsepower (hp) of 3.02, 8.15 and 48.85, respectively. They fish an average of 80 fishing days per boat, landing and earning averages per boat being 5900 kg and 31,650€ respectively. A total of 74 species were landed during that year at the First Sale Spot, with total landings of 118,000 kg which amounted to an income of 633,000€. The 10 species generating the highest income levels were responsible for 72% of the landings and 76% of the income.

The fleet has two basic fishing tactics, firstly, fishing several rock demersal coastal fish species with hook and lines, especially during winter months, and also to a lesser extent during autumn, and secondly, fishing with traps especially during spring and summer. Fig. 4A shows essentiality parameters for the top 10 most essential species. During 2019 there were almost 300 fishing days. From the top 10 species, 6 are categorized as essential, and 3 as fundamental. Playa Blanca's $C_\exists$ value during 2019 is 499, while its $P_\exists$ value is − 0.45.

3.2. Gran Tarajal (SE Fuerteventura)

Gran Tarajal is a medium size fishers' *Cofradía* located on the South-eastern coast of Fuerteventura, in the SE Canary Islands (Fig. 3). Landings data for 2019 from the First Sale Spot show double the figures for Playa Blanca. Forty-three AFUs are characterized by a mean GT, length (m) and horsepower (hp) of 3.5, 8.58 and 43.05 respectively. The average fishing days per boat is 41, landing and earning averages per boat being 6300 kg and 35,350€ respectively. The total number of landed species during that year was 70, with total landings of 271,000 kg, generating an income of 1,520,000€. The 10 species generating the highest income levels were responsible for 81% of both landings and income.

The fleet catches several demersal coastal rock fish species with hook and lines, especially during summer months, and with traps from November to April (when this gear is permitted). Moreover, the fishery is supported by the exploitation of deep-sea resources with electric reel hook and lines throughout the year, and by fishing seasonal tuna fish when available. Essentiality parameters for the top 10 most essential species are presented in Fig/4B. During 2019 there were 263 fishing days. From the top 10 species, only 2 are categorized as essential, and 1 as fundamental. Gran Tarajal $C_\exists$ value during 2019 is 139, while its $P_\exists$ value is − 2.21.

3.3. La Restinga (S El Hierro)

La Restinga, located on the Southern coast of El Hierro, in the SW Canary Islands (Fig. 3), is a medium size fishers' *Cofradía*. Twenty-eight AFUs have a mean GT, length (m) and horsepower (hp) of 2.5, 7.51 and 33.9 respectively. The average number of fishing days per boat is 116, with landing and income averages of 13,000 kg and 37,350€ respectively. During 2019, 57 different species were landed at La Restinga, giving a total of 375.5 t and generating earnings slightly higher than 1 M€. The top 10 species contributed 92% of total landings and 86% of total income.

The fleets direct a large amount of fishing effort towards tuna during the summer months, and a mixture of fishing tactics are used throughout the year, aimed at both coastal and deep demersal resources. Usual fishing gears in the Canary Islands are complemented with exclusive gears from El Hierro such as 'puyón' (snorkelling hook and line) and 'vara de petos' (harpoon for wahoo). Fig. 4C represents the essentiality parameters for the top 10 essential species landed during 361 fishing days in 2019. Regarding the top 10 species in the fishery, 3 are categorized as essential and 5 as fundamental. La Restinga $C_\exists$ value during 2019 was 312, while its $P_\exists$ value was − 1.11.

4. Discussion

This study puts forward a new model for the parameterization of SSFs based on the essentiality that the most fished species have for the economic viability of the fishery. No previous works have dealt with the issue of species essentiality. However, there are many publications that emphasize socioeconomic aspects when evaluating the status of SSFs and their impact on fishing resources and / or the economic viability of the activity, an aim that, in the face of ever-changing circumstances, is always sought after by fishers (Torres-Guevara et al., 2016; Purcell et al., 2017; Schuhbauer and Sumaila, 2016, to cite just a few more recent examples).

In the process of estimating the essentiality of the fishery, an attempt has been made to take into account all those aspects that influence whether a certain species may be more or less essential for a fishery. The only aspect not considered in the analysis is that of seasonality. The F does not allow for differentiation between seasonal species and those that are fished throughout the year, a limitation that would have to be addressed by adding some measure of dispersion.

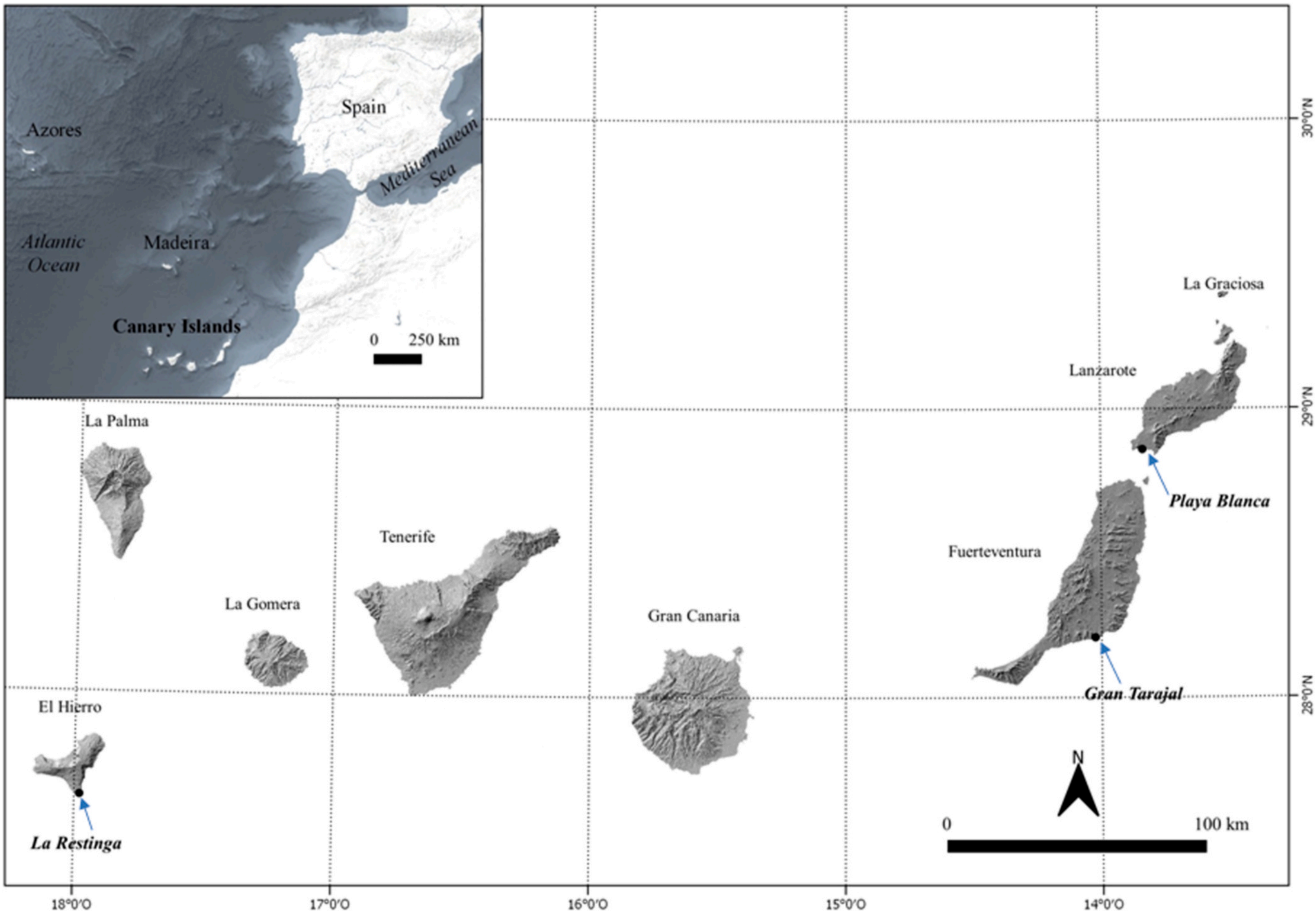

Fig. 3. Map of The Canary Islands with the location of the case studies mentioned in this study.

4.1. Principal implications for SSFs managers and EU common fisheries policy

Estimating the essentiality of the fishery has several utilities. As the case studies illustrate, it allows us to comparatively characterize fishing communities with SSFs of differing characteristics, based on the same yearly data. As an example, the small fishing community of Playa Blanca, which uses only two fishing tactics, achieves a very high essential capacity due to very high F values for all the main species and R values greater than 0.4 for the five most essential species. The essentiality of the species and its ranking is determined mainly by their economic values (*p*). In contrast, Gran Tarajal, with twice the fleet size of Playa Blanca, which takes advantage of some seasonal resources such as tuna, and has a greater variety of fishing tactics, but does not achieve a high essential capacity value. The income obtained from the species with the highest essentiality index from this fishery is quite low. Compared to Playa Blanca, the Gran Tarajal fleet is based on species that are caught less frequently in the fishery (lower F values) and has greater difficulty in incorporating these species in its fishing strategies, despite being more diverse (lower values of R). Finally, in the case of La Restinga, the fleet size is intermediate, and it employs a variety of fishing strategies, including the exploitation of seasonal resources, reaching a high essential capacity value, dues to high income levels from seasonal pelagic resources and parrotfish, and high capture frequencies of most of the top 10 essential demersal species fished throughout the year. One drawback is that La Restinga has some difficulty in recruiting AFUs that incorporate the essential species into their fishing strategies, R values being below 0.3 in 8 of the 10 most essential species.

With this tool at their disposal, the data-limited SSFs managers have the option of introducing management measures that allow the behaviour of the fishery to change towards a situation of greater essentiality, and therefore, of greater economic viability, bringing about a reduction in the pressure focused on limited specific fishing resources. The measures may be conducive to increasing the frequency, fleet recruitment or income values of the most essential species. Using the illustrative case studies above as an example, a fishery manager would not need to take any measures to change the Playa Blanca figures (which are difficult to improve). On the other hand, in the case of Gran Tarajal, it will be necessary to take management measures that would add market value (labelling, market intervention, TAC regulation,.) to the non-seasonal species (especially in years in which tuna fish availability drops) and/or take measures to stimulate shifts in fishing strategies to improve fleet recruiting figures (subsidies for structural boat changes, for equipment, transference of knowledge programs,.). These measures are needed to raise essentiality, and thus, the economic viability of the Gran Tarajal fishery. These last kinds of measures to improve fleet recruiting (R), would also probably improve the already high essentiality status of the La Restinga fishery.

We have developed an ∃ simulator to test the effect of possible measures. Afterwards, once the measures are applied, by estimating their essentiality during subsequent years within that same fishing community, the degree of effectiveness of the measures can be verified and, if necessary, modified as appropriate. The fact that the data are basic and available (without field work) makes the essentiality of fisheries a tool for fast, dynamic, flexible, and adaptive management. This model of fishing essentiality can be applied to any SSF in the world where basic fishing data are available (landings in kg and their value in Euros, by AFU –or failing that, by boat–, by day and by species).

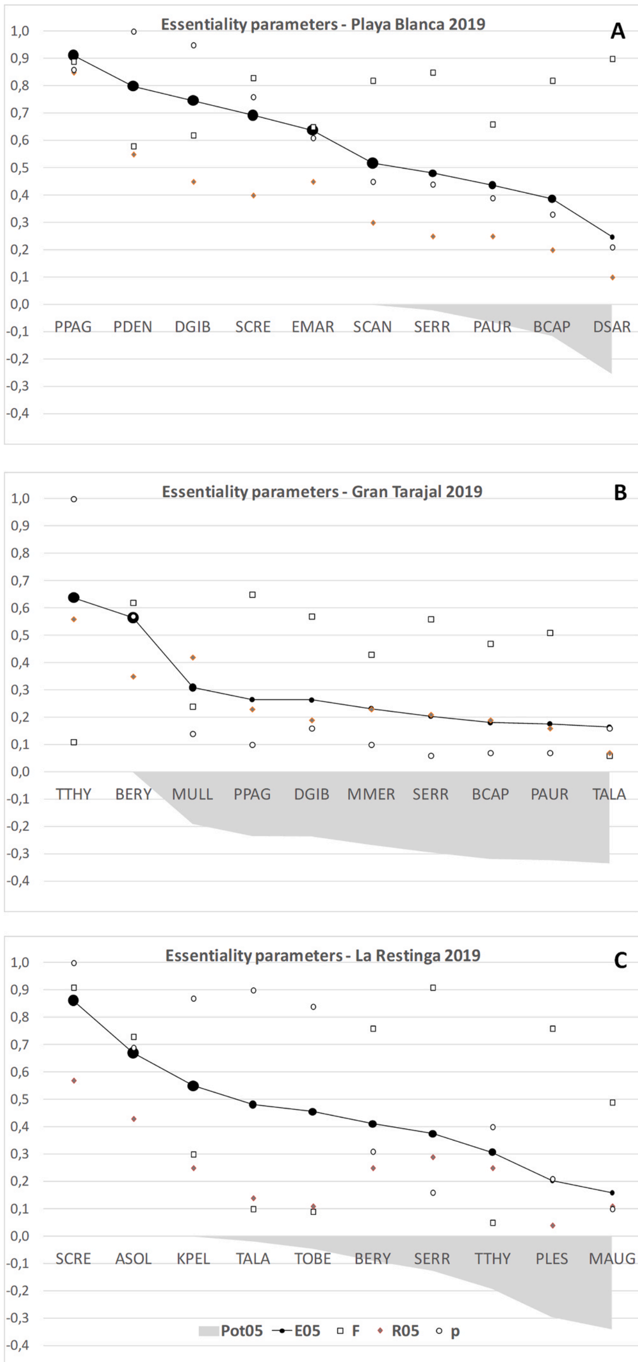

Fig. 4. Species essentiality parameters for the 3 case studies during 2019. F = Frequency; R05 = Fleet Recruiting estimated with a 5% profit threshold; p = Income rate; Pot05 = Essential Potentiality estimated with R05; E05 = Essentiality estimated with R05. Essentiality markers have three sizes, large for essential species, medium for fundamental and small for complementary ones. Taxa categories codes listed in Table 4.

The European Commission, through the STECF (Scientific, Technical and Economic Committee for Fisheries), performs analytical work on the different European fisheries, including the calculation of indicators, both ecological, fishery and socio-economic (Scientific, Technical and Economic Committee for Fisheries STECF, 2019, to quote the latest). The purpose of these reports is to assess the balance between fishing capacity and fishing opportunities. To do this, it makes use of fishing indicators based on traditional fishing profitability concepts such as Maximum Sustainable Yield or Limit Biomass (e.g., Sustainable Harvest Indicator –SHI– or Stocks at Risk Indicator –SAR, see Scientific, Technical and Economic Committee for Fisheries STECF, 2015), which have proven useful for assessing industrial fisheries. Other types of fishing effort indicators are also used for evaluating the balance of European fisheries, such as the Vessel Utilization Rate (VUR, Scientific, Technical and Economic Committee for Fisheries STECF, 2019) that only takes into account the number of fishing days as a measure of effort, without relating this effort to the target species and their essentiality, an analysis that would better reflect the behaviour of the small-scale fishers in search of economic viability.

Gascuel et al. (2012) attempted to build a fleet-based synthesis using indicators of both the ecological impact and economic performances of fleets operating in the ecosystem. Although the work is interesting as a reference point, since it applies an economic perspective to fisheries assessment and uses landing data, the authors deal with large-scale fisheries from the Celtic and North Seas, using traditional stock assessment indicators which the present study aims to demonstrate are not valid for the assessment of SSFs.

4.2. *Future steps on fishery essentiality*

Future research should focus on using historical data series and assessing how the degree of essentiality has been influenced by past management measures. This will allow for testing the usefulness of this model when applied to practical cases. It is recommended that future studies address the combination of the estimation of fishing essentiality with an analysis of the metierization and seasonality of the analysed fisheries, since our understanding of how fisheries function will be enhanced by these complementary analyses. A breakdown of the seasonality of the fishery under study is a perfect complement to the observation of essentiality since the seasonality patterns of the species are not reflected in any of the parameters that contribute to the estimation of essentiality. And a study of the seasonality of the species is always going to be better understood alongside a work of metierization of the fishery, for which information on fishing gear taken from fishing books (Saldaña et al., 2016; Deporte et al., 2012), or reliable landing information is necessary.

It is also recommended that fisheries managers combine essentiality, metierization and seasonality studies with updated stock assessment analyses from the data-limited fisheries (Geromont and Butterworth, 2015; Edwards, 2015). With this information it will then be possible to estimate trends in the level of exploitation (fishing mortality) of the essential species. Considering other types of socio-economic data beyond the economic income derived the sale of landings is also recommended. This would provide a more in-depth analysis when assessing economic viability and the subsequent management measures taken by the SSFs (Purcell et al., 2017; Schuhbauer and Sumaila, 2016).

4.3. *Conclusion*

In conclusion, the parameters of fishing essentiality constitute a new tool of easy and fast application. It allows managers of data-limited fisheries to conduct a diagnosis of the economic viability of the managed fishery, based on basic landings data, and to establish management measures conducive to improving this economic viability, taking advantage of the polyvalence, versatility and multi-specificity conditions of the SSFs.

In summary, the essentiality of the fishery is presented as an alternative method of assessment and management of the fishery to the traditional evaluation methods used for industrial fisheries. This is significant given the characteristics of the SSFs and the peculiar behaviour of small-scale fishers in favour of the economic viability of their activity. Due to these facts, establishing traditional control measures, both of effort and catch (input or output), is not the best method to manage SSFs. The evaluation of fishing essentiality informs us of the necessary changes in management measures that are required to achieve a redistribution of fishing effort in order to alleviate the pressure on the most exploited resources while facilitating the economic viability of a determined fishing community.

CRediT authorship contribution statement

Dorta, C.: Conceptualization, Methodology, Formal analysis, Resources, Supervision. **Martín-Sosa, P.**: Methodology, Software, Investigation, Data curation, Writing, Visualization.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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