MÉTIERS, EFFORT AND CATCHES OF A MEDITERRANEAN SMALL-SCALE COASTAL FISHERY: THE CASE OF THE GULF OF LION MARINE NATURAL PARK

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Abstract – Littoral ecosystems are under a variety of threats including overexploitation of fishery resources which has led to a major fisheries crisis. In this context, Marine Protected Areas (MPA) have been established around the world to counter the overuse of these ecosystems and serve notably as management tools for the fisheries. Within MPAs, policymakers along with scientists need data to decide on the implementation of new measures, to estimates their effects and to adapt their management accordingly. The objectives of this study were to describe at a spatio-temporal scale, the characteristics of the Small-Scale Fisheries (SSF) in the Gulf of Lion Marine Natural Park (GLMNP), an MPA located in north-west Mediterranean. Common tools such as fishing effort, Catch Per Unit Effort (CPUE) and "métiers", defined by the use of a fishing gear with a targeted species, were used. A field protocol was implemented to collect data through questionnaires to fishers at landing sites during a study period of one-year between April 2019 and March 2020 within the GLMNP. A total of 35 fishers (67 % of the active fishers) from the 7 fishing harbours responded to our questionnaire and 167 trips on fishing ports have been realized. During these trips, 5219 days of fishing activity or inactivity and 510 fishing operations were collected from the SSF fleet within the GLMNP. The most frequently used métiers were the hake gill net and the sparids trammel net and gill net, targeting two predominant species: hake (*Merluccius merluccius*) and gilthead seabream (*Sparus aurata*). The spatial distribution of the fishing operations seemed to depend on the proximity to the harbour, on the knowledge and habits of the fishermen and also on a spatial competition that may occur among fishers targeting the same species or group. The methodology used in this study is part of a long term monitoring requiring close collaboration with local fishers. It is expected to enable adaptive management to contribute to the sustainability of SSF notably through measures related to fishing pressure which may impact the environment and its resources.

Introduction

Fisheries across the world remain for millions of people, a vital activity, providing various ecosystems services (e.g. food and cultural services such as recreational and artisanal

fishing) [8, 24]. The industrialization of the 20th century has favored the increase in the number of boats as well as their power and the emergence of new technologies such as the Satellite Positioning System (GPS) or the echo-sounder. Especially in the Mediterranean, and mostly for the Large-Scale Fishing sector (LSF), these innovations have greatly contributed to the increase in fishing pressure exerted on the habitats and species [13, 22]. Regarding the Small-Scale Fishery (SSF) (or artisanal fishery), it includes boats not exceeding twelve meters and operating onshore for trips of less than 24 hours [5, 7, 11, 26].

This sector is undergoing a serious crisis in Europe because of compete for resources and space with many emergent activities such as tourism, exploitation of fossil and renewable energies and transport [11,18]. In the Mediterranean, 72 % of the EU fleet belongs to SSF with a total of 34 976 active vessels accounting to about 70 000 jobs. Regarding landings and effort, LSF contributes respectively to 89 % of the total weigth (78 % by value) and 36 % of the effort. The SSF represents 11 % of the total landed-weigth (22 % of the landed value) and deployed 64 % of the effort [23]. Despite this low amount of landings and the decrease of its importance for the EU's fleet in the northern Mediterranean, the SSF sector is of high cultural and socio-economic importance and is well anchored in Mediterranean countries [17]. The SSF maximizes the economic value of the diversity of resources it exploits by selling their products at higher prices compared to the LSF. Moreover, the products are mainly destined to tourist markets or local markets (either in fish stalls, or to the restaurants) [3, 11, 23]. The artisanal fishery is characterized by the use of numerous fishing gears (gill nets, trammel nets, longline, pots, basket traps) targeting a wide range of species. The term "métier", or fishing tactics, is used to define the combination of a fishing gear with a targeted species in a given season. The use of these "métiers" may also change according to the seasonal dynamics of the resources [4, 17, 26]. This approach of the fishing tactics is likely to be useful to understand the spatio-temporal patterns of the fishing effort allocation and related catches [14, 26]. Due to the diversity of tactics used and the high selectivity of the target species, thus allowing much less discards, the SSF appears to be a relatively sustainable modes of exploitation of coastal resources in comparison with the LSF such as trawling. Nevertheless, it is difficult to accurately evaluate these fisheries because of the large number of fishers located in multiple harbours [15, 16, 20]. Due to the development of maritime transport, tourism and urbanization, artisanal fisheries must face increasing constraints in order to maintain their activity. Thus, the Common Fisheries Policy in Europe raises the matter of taking greater account of the SSF [6, 11] and requires integrating ecological, technological and socio-economic approaches to the study of fisheries [1, 17]. The SSF remains poorly evaluated and compared in the Mediterranean, and particularly on the scale of an MPA. The latter are however recognized as tools for managing these fisheries via the spillover effect [7] notably resulting from the implementation of several measures such as fishing effort limitations, minimum catch size or seasonal closure. In view of the growing challenge of sharing space (renewable marine energies, extractions, submarine cables, leisure and professional fisheries, etc..), managers of the Gulf of Lion Marine Natural Park (GLMNP), located in northern Mediterranean, aim at supporting the implementation of a long term management plan for the sustainability of the SSF. For this purpose, many surveys of this activity were implemented particularly in collaboration with researchers from the CEFREM laboratory since 2007.

The objectives of this study, through the "PechePro" project, were to determine spatio-temporal characteristics of the SSF using landing data on a year round survey. Firstly,

the main technical characteristics of the SSF were described in the various harbours. Secondly, catches and métiers were described and spatialized using fishing effort and Capture Per Unit of Effort (CPUE). The latter being a commonly used measure for comparing regional and temporal trends by providing an estimate of the abundance of a fish stock and also serve as an indicator for the impact of the SSF activity on resources [19,27]. Thirdly, comparison and evolution of CPUE and fishing effort between 2012 and 2020 by métier were realized.

Materials and Methods

The GLMNP located in the gulf of Lion continental shelf, north-western Mediterranean Sea (42°40' North, 3°5' East) was established in 2011 (Fig. 1). This MPA of 4010 km² stretches over 100 km from Cap Leucate to the border with Spain at Cap Cerbère. It comprises the Marine Natural Reserve of Cerbère-Banyuls (MNRCB) established since 1974. The heterogeneous coastal shelf consists of 70 km of sandy coast in the north and 30 km of rocky coast in the south. This coastal area is the spillway of numerous rivers and it also communicates with two ponds through several "graus". The bigger is the Salses-Leucate pond on the north that was included in the survey because of the mixt activities of the fishers between sea and pond. The SSF survey took place in the 7 main fishing harbours (Port-Leucate, Port-Barcarès, Canet-en-Roussillon, Saint-Cyprien, Argelès-sur-Mer, Port-Vendres and Banyuls-sur-mer). The GLMNP includes three "prud'homies" (local fisher's guild) which manage and coordinate their attributed area and insure the communication with the GLMNP through meetings and steering committees. From different scales: (i) European Union, (ii) National and (iii) Local (Prud'homies), regulations are already enforced respectively through several measures within the GLMNP: (i) e.g. maximum fishing net length, (ii) e.g. minimum catch size and (iii) access regulation (mainly within the MNRCB) or number of pots and traps.

After having determined an actualized list of the active and non-active vessels and their main features through registries of the European fleet and maritime offices (engine power, gross tonnage, overall length), the SSF characteristics were generally collected by 2 persons during harbour trips. It encompassed the fishing technique, targeted species, net length and heigth, mesh size, soak time, location, depth, catch estimation and species total length and weight. Interviews with skippers (most often the vessel owner) were conducted about every day including weekends (excepted sunday) during the opening hours of the fishing stalls (8 am to 12 pm). In total, 35 of the 52 active fishers answered at least once to the survey during a one year period. The last third whether refused to answer to the interview or were not seen on harbours dock. Fishers working exclusively in the ponds were not included in the study. Field survey to collect landing and effort data in 6 harbours, Canet-en-Roussillon excluded, were realized depending on the weight of the fishing activity i.e. number of active boats. Between April 2019 and March 2020, a total of 510 interviews were conducted during 167 mornings spent on harbours. The questionnaire was related to the daily fishing trips and the use of one métier corresponded to one fishing operation (e.g. hake gill nets). Fishers drawn their operation's location on a standard NHOS map (Naval Hydrographic and Océanographic Service) and all 510 operations were plotted into a

Geographical Information System (QGIS 3.6® software). Discards were rarely observed because fishers usually rejected them overboard on their way back to the fishing port.

According to previous studies, the catches of SSF were assumed to be equal with the landings because of the few discards. Discards included damaged specimens, species under the minimum catch size and species which could not be sold e.g. *genus Torpedo* [17]. Then, informations about substratums (sand, mud, rock) were collected using open access websites [12].
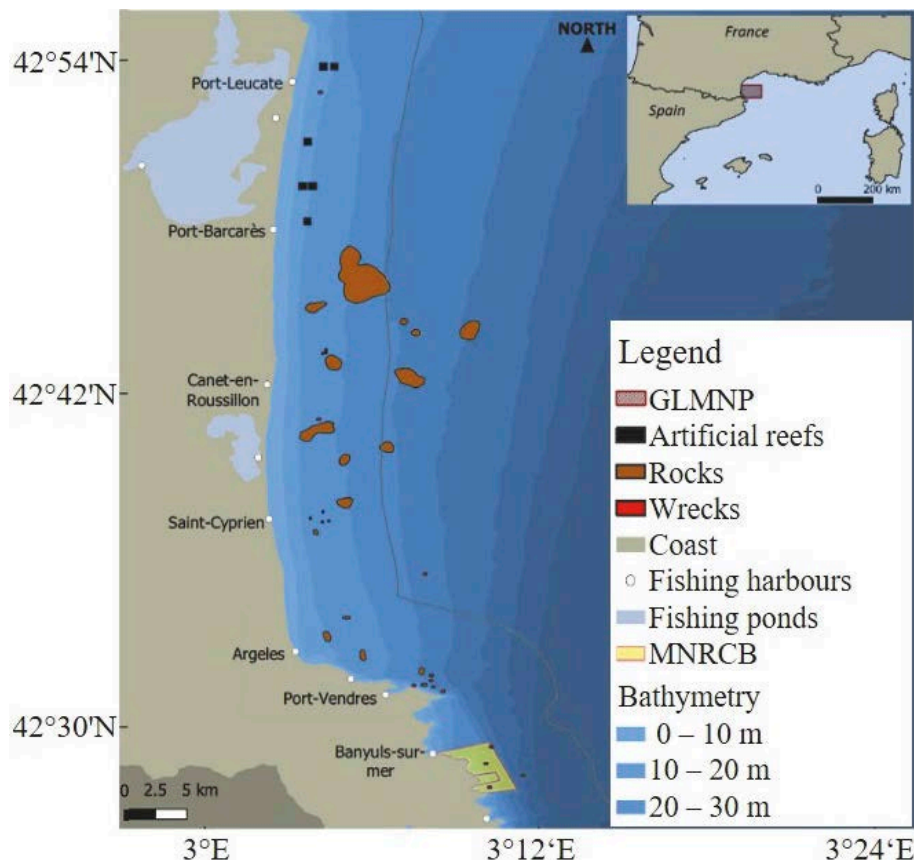

Figure 1 - Location and characteristics of the study area (Gulf of Lion Marine Natural Park) on the north-western Mediterranean and the main fishing harbours.

In this study, and in order to compare data with other study area throughout Mediterranean, different clusters (group of species) were defined according to the declared target species and comprised all the Fishing Operations (FO) related to that species or group targeted. The cluster "sparids" included métiers targeting *Sparus aurata* and *Pagellus*

erythrinus with gill net, trammel net and combined. The latter species was targeted with gill net with similar characteristics as the gilthead seabream' gill net in term of mesh size, net height and length. Flatfishes cluster corresponded to métiers targeting soles, turbot and brill as the turbot and brill were often targeted as secondary species or considered as associated catch [15]. Catch (or more precisely landings) per unit effort (CPUE) was expressed as the total volume of fish landed in kilogram per 100 meters of nets [15, 19, 27]. Statistical analyzes were performed on the data collected for the whole year using Excel® and Rstudio 3.5.1® software [21]. Fishing effort and CPUE between data collected in 2012 [2] and 2020 were analysed through non-parametric Wilcoxon Mann-Whitney test [28].

Results

During the study period, data pertaining to 45 boats, out of 67 active boats, were analysed. Average characteristics of the 78 active and inactive SSF vessels were 7,38 ± 1,6 meters' length, 31 ± 14 years, 2,51 ± 1,99 gross tonnage and 80,57 ± 59,59 kW. The most active fishing harbour was Port-Barcarès, followed by Port-Vendres and the less active that of Canet-en-Roussillon (Table 1).

Table 1 - Number of boats and technical characteristics of the Small Scale Fishery fleet in the 7 harbours within the Gulf of Lion Marine Natural Park in 2020. YOC: Year of Construction, LOA: Overall Length, HP: Horse Power, GRT: Gross Register Tonnage. sd: standard deviation.

Harbours	Active boats	Characteristics of all boats (mean ± sd)			
		YOC	LOA	HP	GRT
Argelès/mer	3	1997 ± 9,8	7,8 ± 1,5	123, 3 ± 75,7	3,8 ± 1,5
Banyuls/mer	4	1982 ± 19,6	7,6 ± 2,3	74,8 ± 67,7	3,1 ± 3,5
Port-Barcarès	24	1988 ± 15,3	6,7 ± 1,3	70,4 ± 64,8	1,5 ± 1,1
Canet	2	1969 ± 6,4	7,1 ± 1,3	72 ± 24	1,5 ± 1,2
Leucate	12	1993 ± 14,8	6,6 ± 1	62,3 ± 43,7	1,7 ± 1,2
Port-Vendres	13	1982 ± 10,2	8,4 ± 1,9	90,8 ± 44	3,2 ± 2,7
Saint-Cyprien	9	1992 ± 11,4	8,8 ± 1,8	119,8 ± 73,3	4 ± 2,7

In total, 6 clusters were identified and corresponded to: sparids (138 fishing operations), hake (107), cuttlefish (46), red mullet (44), flatfishes (37) and monkfish (24). Except for the "sparids", each métier used a single gear. Three métiers "hake", "sparids" and "flatfhishes" were used almost throughout the whole year (Table 2). The "red mullet" métier was mainly practiced during late spring-summer, while "cuttlefish" and "monkfish" were principally used during winter-spring. Relating to fishing ground, each métier was practiced in distinct habitats and depths. The "monkfish" and "hake" métiers were preferably performed above detritic muddy bottom (79 % and 86 % of the fishing net length). Flatfishes and red mullet were mainly targeted on detritic sand or detritic rock and coarse sediment (86 % and 80 % respectively), whereas cuttlefish were fished near-shore on sand or mud (76 %) and

the sparids were targeted on mixed substrates as well as in the ponds where it accounted for 37 % of the "sparids" métiers. Fishers using nets practiced an average of $1{,}4 \pm 0{,}61$ fishing operations, $1{,}3 \pm 0{,}57$ métiers and set an average of $1733{,}8 \pm 1209$ m per fishing trip. The "flatfishes" and "monkfish" métiers used the longest lengths of net per fishing operation although "red mullet" métier represented the shortest average length. The "hake" and "sparids" métiers had the largest CPUE in comparison with the "flatfishes", "cuttlefish" and "red mullet" métiers which showed the lowest CPUE (Table 3).

Table 2 - The 6 main clusters are described through fishing period, number of boats practicing the métier and Fishing Operations (FO). Fishing period corresponds to the shading: no shading (< 5 % of fishing operations observed during the month); light shading ([5-10] %); dark shading (>10 %). Mean depth, net height, mesh size (non stretched) are also shown. sd: standard deviation.

Cluster/Métier	Fishing period 2019 A M J J A S O N D — 2020 J F M	Boats	FO (%)	Depth (m)	Net height (m) ± sd	Mesh size (mm) ± sd (range)
Cuttlefish		21	9	8 ± 5	$1{,}63 \pm 1{,}37$	$44{,}2 \pm 9{,}3$ (35÷100)
Flatfishes		15	7	23 ± 19	$1{,}43 \pm 0{,}27$	$59{,}5 \pm 24{,}8$ (35÷100)
Hake		18	21	46 ± 19	$6{,}7 \pm 5{,}45$	$32{,}6 \pm 1{,}8$ (31÷35)
Monkfish		11	5	67 ± 32	$1{,}59 \pm 0{,}81$	$83{,}3 \pm 16{,}4$ (45÷120)
Red mullet		13	9	19 ± 5	$1{,}33 \pm 0{,}31$	$22{,}1 \pm 3{,}8$ (16÷40)
Sparids		33	27	12 ± 12	$4{,}85 \pm 3{,}89$	$43{,}1 \pm 6{,}3$ (30÷75)

Fishing effort and CPUE were statistically compared among the 6 main clusters between 2012 and 2020 (Table 3). Results indicated that mean length of net per fishing operation were significantly higher in 2020 for 3 clusters only: "cuttlefish", "sparids" and "all nets". Concerning CPUE, the "hake" métier showed the most significant increase between 2012 and 2020 (N = 184, W = 2232, p-value = 1,192e-7: ***). The "all nets" cluster also displayed a significantly higher value in 2020 than in 2012 (N = 937, W = 91494, p-value = 5,7e-3: ***). For the 5 other métiers, no statistical differences were observed despite a slight decrease in yield for the "cuttlefish" and "sparids" métiers and a low increase for the "red mullet" métier.

Spatial distribution of the SSF using nets (465 fishing operations) generally occurred within the 3 nautical miles strip and were quite well distributed along the GLMNP coast and in the Salses-Leucate pond (Fig. 2). In the latter, CPUE were relatively low $(0{,}92 \pm 1{,}21$ kg 100 m$^{-1})$ compared with marine areas $(2{,}66 \pm 4{,}47$ kg·100 m$^{-1})$ and mean net lengths were generally higher 2251 ± 1363 m than those obtain at sea $(1577 \pm 1112$ m). The CPUE seemed also higher on mixsubstrates at Cap Leucate in the north and between Argelès-

sur-mer and Banyuls-sur-mer in the south. Besides, a small proportion of the fishing activity occured off-shore in the deep sea canyons but the CPUE did not seem to be higher than within the 3 nautical miles.

Table 3 - Statistical comparison (through Wilcoxon Mann-Whitney tests) and evolution of CPUE and fishing effort between 2012 and 2020 by métier in the Gulf of Lion Marine Natural Park. P-value and Mann-Whitney (W) value are also shown. Levels of significance were *p ≤ 0,05; **p ≤ 0,01; ***p ≤ 0,001.

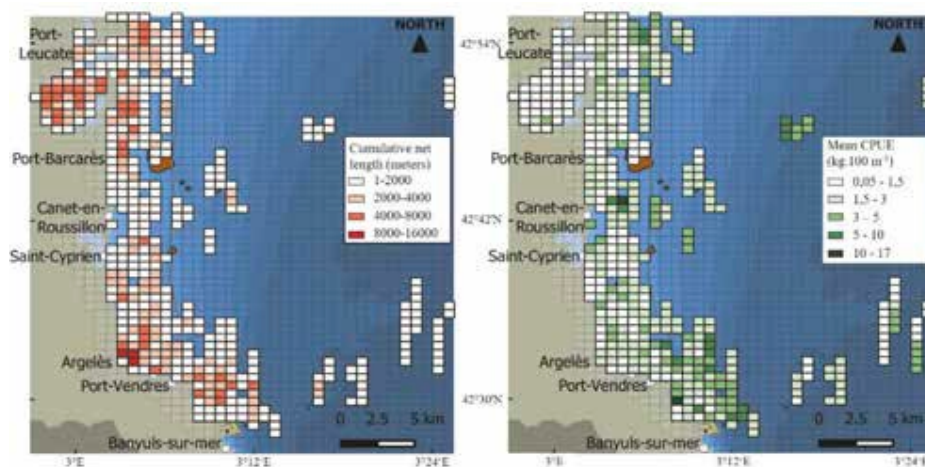| Cluster	Fishing effort (m)		W, P-value	CPUE (kg·100 m⁻¹)		W, P-value
	2020	2012		2020	2012	
Cuttle fish	1896 ± 865	1461 ± 887	786, 0,010 **	1,18 ± 0,73	1,63 ± 1,43	1286,0 0,24
Flatfishes	2757 ± 1978	2274 ± 2292	727, 0,88	0,97 ± 0,8	0,82 ± 0,63	823, 0,38
Hake	1739 ± 807	1885 ± 898	4461, 0,33	3,49 ± 2,51	2,01 ± 1,61	2232, 1,19e-07***
Monkfish	2563 ± 1349	2200 ± 570	57, 0,88	1,72 ± 1,07	1,88 ± 0,76	71,0 0,56
Red mullet	1102 ± 335	1122 ± 541	1429, 0,78	1,23 ± 0,97	0,96 ± 0,8	1220, 0,13
Sparids	1550 ± 1230	1115 ± 1004	6834, 2,9e-03 ***	2,33 ± 2,75	2,52 ± 3,59	8756, 0,89
All nets	1702 ± 1162	1393 ± 1205	81715, 1,3e-07 ***	2,14 ± 2,26	2,09 ± 3,19	91494, 5,7e-03 ***

Figure 2 - Spatialisation of the fishing effort (cumulative net length in meters) and Catch Per Unit Effort (in kg·100 m⁻¹) for all fishing operations using net (gill net, trammel net and combined) within the Gulf of Lion Marine Natural Park. Brown spots correspond to the location of rocky plateaus.

Discussion

The Mediterranean artisanal fishing fleet within the GLMNP is typical because boats characteristics observed in this study are similar with those observed in other French Mediterranean areas [15], Spanish areas [7, 17] or in Italy [4]. The main fishing techniques were the trammel net and gill net even though pots and longline were used very frequently. The tuna longline and octopus pots and baskets were métiers well represented in our data (11 fishing operations, 2,2 %, and 24, 4,7 %, respectively). A total of 18 boats targeted octopus and 7 used tuna longline but both métier could not be analyzed in a consistent manner, despite the fact that they greatly contribute to the SSF economy within the GLMNP, because landings rarely occurred during the opening hours of stalls.

A particular emphasize should be done on the study of *Octopus vulgaris*, a species caught by several gears and considered as the second species of importance for the Spanish SSF [10]. Our results show that from the 38 métiers observed within our study zone, 6 targeted species (namely clusters) represented most of the fishing operations (78 %) and among these 6 clusters, 5 are well represented in other Mediterranean SSFs in terms of seasonality and occurrence (e.g. cuttlefish, flatfishes, hake, octopus, red mullet and sparids [4, 15, 17, 26]. Concerning catches, and except with clusters "hake" and "all net" for which mean CPUE increased significativly from 2012 to 2020 within the GLMNP, annual CPUE remained globally stable between the two study periods (Table 2) [2]. This would be in agreement with the study of García-Rodríguez and collaborators [10], which observed very fluctuating abundance from year-to-year. Even though fishing characteristics may vary greatly among Mediterranean area (mesh size, or net height and length), our data are consistent with other studies regarding yields [7, 15].

Indeed, the sustainability of the SSF is enabled with the great dynamism of the fleet, which is capable of changing fishing tactics/métiers by alternatively using different fishing gears depending on the abundance of the target species [10]. The observed distribution pattern of the SSF within the GLMNP is also in agreement with the SSF around Mediterranean as the main factors seeming at stake are for example fisher's knowledge, species abundance, closeness with harbour. This can also be explained by the captains' desire to avoid trawler fishing areas located beyond 3 nautical miles. Indeed, the latter have severely damaged their materials in the past. In this study, all species caught by the SSF had mostly reached maturity. For instance, red mullets were caught near shore at sizes over 15 cm Total Length (TL), hakes were constituted by specimens over 30 cm TL and gilthead seabream were over 20 cm TL. Hence, besides avoiding spatial competition with trawlers, catches from the SSF greatly contrast with trawling activities which capture immature individuals for several species (i.e. octopus, hake, and red mullet [9,10,25]). From this point of view, SSF can be considered as relatively sustainable fisheries because it also has very low level of bycatch and discards such as suggested by García-Rodríguez and collaborators [10]. The results from this study should nevertheless be nuanced because discards were not precisely known.

To conclude, the main threat to SSF in Europe seemed to be LSF (trawlers mostly), followed by recreational fisheries [11]. Furthermore, as stated by most fishers, they catch smaller quantities of fish in order to sell at fishing stall rather than at the auction where prices are 2 to 5 times lower. Selling on short supply chains throughout the year would therefore be the most effective way to empower this fishery to remain economically sustainable. Selling,

even partially at auction could contribute greatly to increase fishing pressure, thus increasing competition for resource with those who have found economic alternatives. These aspects should be used by decision-makers for promoting SSF products for instance by creating "eco-labelling" sea products [17].

Acknowledgments

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