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**A novel use of social media to evaluate the occurrence of skin lesions affecting wild dusky grouper, *Epinephelus marginatus* (Lowe, 1834), in Libyan coastal waters**

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*Running title:* Skin lesions of dusky grouper

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## Abstract

The social media network Facebook<sup>TM</sup> was used to gather information on the occurrence and geographical distribution of dusky grouper dermatitis (DGD), a skin lesion affecting the dusky grouper, *Epinephelus marginatus*. Dusky grouper are common targets for spear fishermen in the Mediterranean and by monitoring spearfishing activity in Libyan waters, it was possible to document skin lesions from their entries on Facebook. Thirty two Facebook accounts and 8 Facebook groups posting from 23 Libyan coastal cities provided a retrospective observational dataset comprising a total of 382 images of dusky grouper caught by spearfishing between December 2011-December 2015. Skin lesions were observable on 57 / 362 fish, for which images were of sufficient quality for analysis, giving a minimal prevalence for lesions of 15.75%. Only dusky grouper exceeding an estimated 40 cm total length exhibited lesions. The ability to collect useful data about the occurrence and geographical distribution of pathological conditions affecting wild fish using social media networks, demonstrates their potential utility as a tool to support epidemiological studies and monitor the health of populations of aquatic animals. To our knowledge, this represents the first time that such an approach has been applied for assessing health in a wild population of fish.

Key words: Facebook, YouTube, dusky grouper dermatitis, DGD, disease surveillance

## Introduction

The majority of Libya's population reside in its coastal cities, with over 2 million people living in the capital Tripoli. With a 1,770 km coastline, much of the country's fish derives from capture fisheries. In 2013, for which the last figures are available, the total tonnage was 36,000 mt, valued at US\$ 100 million (FAO FishStatJ 2015). While most fishing activities are artisanal, fishing operators are obliged to hold a fishing permit issued by the Libyan Secretariat of Marine Wealth (Reynolds, Lamboeuf, Ben Abdallah, Abukhader, Abdulbari & Nafati 1995). Spearfishing, however, remains an uncontrolled fishing practice, whose captures are not visible in formal landing statistics. The dusky grouper is considered a high quality food fish and is caught by artisanal means as well as by spearfishing in Libya (Kasem, Ben Abdallah, Treky & Mosa 2009). A field study of local fish markets in Tripoli, conducted between 2013-2015, revealed that approximately 300 spear fishermen were supplying a local fish market in Tripoli (unpublished data).

The dusky grouper, *Epinephelus marginatus* (Lowe, 1834) [syn. *E. gigas*, *E. guaza*] (Perciformes, Serranidae), is a protogynous, monandric, hermaphroditic teleost endemic to the Mediterranean Sea with an extensive distribution (Heemstra & Randall 1993). The dusky grouper is currently listed as being endangered by the IUCN (EN A2d) (Cornish & Harmelin-Vivien 2004; IUCN, 2015).

As a K-strategist, female dusky grouper in the western Mediterranean reach sexual maturity at about 5 years of age at 38.6 cm total length (TL) (Reñones *et al.* 2010). Males, however, reach sexual maturity around 7 years of age at 58.4 cm TL (Reñones *et al.* 2007). The maximum recorded size for this species being 120 cm TL (Heemstra & Randall 1993). The

oldest recorded individual was 61 years old (Reñones *et al.* 2007). While a number of grouper species are important as commercially landed or sport fish species (Leong, 1998), the dusky grouper is considered to be the highest quality food fish and in Libya it is commonly found at fish markets priced at 10-34 Libyan Dinars (LD) kg<sup>-1</sup> (*i.e.* US\$ 7.3 – 24.8). Given its perceived value, flesh quality and large size, increasing pressure is being placed on local dusky grouper populations by spearfishing (Reñones, *et al.* 2007), a fishing method with dusky grouper as one of its main targets (Morales-Nin, Moranta, García, Tugores, Grau, Riera & Cerdà 2005).

### ***Dusky grouper dermatitis (DGD)***

DGD is a condition characterised by the presence of skin lesions affecting dusky grouper sized between 42-92 cm TL (Rizgalla, Bron, Shinn, Herath, Paladini & Ferguson 2016) and is described from fish that were caught by spearfishing and sold at a fish market in Tripoli between 2013-2015. The observed skin lesions are of unknown aetiology, and were classified according to their gross and histopathological presentation into either mild, moderate or severe dermatitis (Rizgalla *et al.* 2016).

Grossly, skin lesions were evident either as reddened patches or as whitish lesions with haemorrhagic ulceration and scale loss. The lesions could comprise multiple foci, and were unilateral or bilateral. They affected both the head and flanks, ventral and dorsal aspects, and the caudal peduncle. Lesions on the head were frequently seen on the skin covering the operculum posterior to the eye (Rizgalla *et al.* 2016). No evidence was found for a bacterial, fungal or viral aetiology of the lesions but the presence of blood flukes suggested the possibility of parasite involvement (Rizgalla *et al.* 2016). In 2014, a dusky grouper presenting

similar skin lesions was reported from Benghazi (32°11'N; 20°03'E), situated approximately 1,050 km to the east of Tripoli, suggesting that these lesions were not confined to the population of fish around Tripoli but might instead affect dusky grouper over a much wider geographic range (pers. obs.). Attempts to further investigate the epidemiology and occurrence of the lesions using conventional methods such as literature searches, and questioning of fishermen at local fish markets failed to provide sufficient epidemiological data for analysis.

Online Social Networks (OSNs) provide a platform for individuals to self-promote (broadcast) and maintain relationships (Underwood, Kerlin & Farrington-Flint 2011). This offers a constant stream of information posted online (Lima & de Castro 2014) that is shared among groups with common interests, helping to create and strengthen social links (Ellison, Steinfield & Lampe 2007). The increasing scale of such networks brings a commensurate expansion of access to information. Facebook<sup>TM</sup> provides an example of the scale of these networks, with the site hosting 1.65 billion active users per month (Facebook 2016) and therefore comprising the largest network of active users (Olmstead, Mitchell & Rosenstiel 2011), with 350 million new images uploaded daily (Henschen 2013). By comparison, the video-sharing website YouTube<sup>TM</sup> has 1 billion users, while the search engine Google<sup>TM</sup> supports c. 3.5 billion searches a day (Anon, 2015a, b).

The extensive connectivity and broad knowledge base that such activity builds has attracted the attention of academia and industry alike (Boyd & Ellison 2007). OSNs have thus been widely used by researchers, who have employed data obtained through user completion of survey instruments, often cross-validated against data obtained through direct access to Facebook user profiles (Ryan & Xenos, 2011; Golbeck, Robles, Edmondson & Turner 2011).

With the internet providing an increasingly powerful resource for disease surveillance in relation to human and animal pathogens, it has been extensively used by governmental and non-governmental entities to collect, as well as to disseminate information (Brownstein, Freifeld & Madoff 2009; Bernardo, Rajic, Young, Robiadek, Pham & Funk 2013). Bernardo *et al.* (2013) conducted a structured review of the research use of social media between 2002-2011, including Facebook, Twitter<sup>TM</sup> and Google, for surveillance of infectious diseases. The review concluded that despite possible biases, disease surveillance through use of social media can be used to support existing surveillance programs. Images and comments posted by individuals online, coupled with use of online survey instruments or direct questioning, can prove very effective during the investigation of disease outbreaks. For example, a case was described by Stuart Chester, Taylor, Sandhu, Forsting, Ellis, Stirling & Galanis (2011) in which a campylobacteriosis outbreak affecting participants in a bike race, led to the organisers notifying the CDC. Following examination of images and information posted by participants, the "mud" appearing in images was analysed and subsequently identified as the source of infection.

Recreational and sporting aspects of spearfishing, coupled with the scope for competitive comparison of catches, mean that spearfishing individuals seek out others with similar interests, with whom to share their relative experiences and details of their catch. The aim of the current study, therefore, was to use a variety of search engines, social networks and video sharing websites, *e.g.* Google, Facebook and YouTube, to seek out information regarding dusky grouper caught by spearfishing in Libyan waters and in the neighbouring countries of Tunisia, Algeria and Egypt, with the purpose of determining the prevalence and geographical distribution of skin lesions in this region.

## **Materials and methods**

### *Generic data collection via internet searches*

The search space used to collect data comprised the following sites and databases: Google, Facebook and YouTube. For all search engine, social network and video-sharing website queries, a defined list of query terms was employed to interrogate the databases in order to collect data concerning grouper, spear fishing activity and skin lesions. The query terms, employed in a variety of combinations, were: “grouper”, “fishing”, “dusky grouper”, “Libya” “Libyan”, “Mediterranean”, “spearfishing”, “diving”, “wound”, “skin”, “lesion” “scratches” “fish” and their equivalents in Arabic.

### **Facebook**

Facebook was used to conduct a retrospective search, using images of fish included in spearfishing posts, to survey for presence of lesions on captured dusky grouper. The earliest relevant entry discovered comprised a personal Facebook page from 2011. This provided a study period beginning in December 2011 and spanning four years to December 2015.

Two approaches were used for data collection. The first approach involved following Facebook groups having an interest in spearfishing, these being individually identified and having all their postings screened for content relating to the capture of dusky grouper, particularly content with appended images, which could be examined for the presence of skin lesions. The second approach involved following active members posting pictures and footage of dusky grouper fishing activities and tracing them back to their personal Facebook profiles to see whether they had posted further materials of relevance. Facebook friends of



members who commented on a particular piece of relevant content (*e.g.* a “like” vote), were also traced and followed, with priority being given to those that also posted personal images of dusky grouper caught within the specified timeframe set for this study, or posted images of spearfishing in their personal Facebook profile picture posts.

### ***Google and YouTube***

A similar approach, with the use of the same key words, was taken to search for relevant material, images and video footage of dusky grouper fishing activity within Libya using the Google search engine, from which spearfishing web sites were found. The same approach was applied to the YouTube video sharing website, which provides access to content comprising video footage of grouper fishing activities in Libya and the surrounding region.

### ***Estimating the size of fish posted on Facebook and the occurrence of lesions***

Information concerning dusky grouper capture that was posted on Facebook was grouped into five size categories of 20-29 cm, 30-39 cm, 40-49 cm, 50-59 cm and >60 cm (Table 1). Where the weight and / or total length of the grouper were not specified, these parameters were estimated. This was achieved through scaling against known-size recognisable objects within each photograph, *e.g.* branded plastic bottles, equipment *etc.*, or where reference objects were not evident, the height of the fisherman (assuming an average height of 168-170 cm), the length of their arm (assuming a standard 1 m length) and /or the size of their feet (estimated at between 30 to 35 cm) were used as a scale to estimate the size of each fish specimen, providing it was held sufficiently close to the body.

### ***Categorising the spearfishing methods used***

Information regarding the spearfishing methods was also collected and used to categorise fishermen. These data included: when the dive took place (day or night), whether they used air tanks (*e.g.* scuba diving using up to four tanks for a dive period) or if air pumped from the surface was used (as reported by two Facebook users), whether the dive started from the beach by foot or from a boat *etc.*, the dive depth, and the number in each fishing party.

### ***Processing dusky grouper catch data from Facebook***

To avoid the duplication of information, the process of downloading relevant images of dusky grouper fishing activity, with and without evident skin lesions, proceeded from the earliest posting on the Facebook page towards the most recent entry. Data were collected and sorted by closest city, with relevant data used for an estimation of lesions in relation to the total number of fish landed per person, the method of fishing used, the time of year, water depth and the temperature, where provided.

An archive of all dusky grouper pictures accessed was kept for this study and checks were applied to the photographs posted between accounts / groups to ensure that the statistics presented were based on unique records. The size of fish, and the species of grouper were not always possible to assess, thus some fish records / postings were discarded as the quality of the images was not sufficient to obtain accurate data.

Permission to use selected pictures and footage for the current work was obtained by directly contacting Facebook members, some of whom were Facebook “friends of friends”. Contributors are noted at the end of this document in the acknowledgments section.

## Results

### ***Facebook groups with special interests in spearfishing and scuba diving in Libya***

Within the study period, 12 Facebook groups were found, six with open access and six accessible only by members. All the groups had an interest in fishing by free diving and by scuba diving in combination with spearfishing. The largest group had 29,626 members during the study period and 32,077 members as of the 4<sup>th</sup> March 2016, drawn from across Libya and the neighbouring countries of Tunisia, Egypt and Algeria. The smallest interest group had only 7 members, with the oldest group (closed access) being formed in 2010 and the most recent formed in 2015 (closed access). For closed access groups no data could be directly accessed beyond their entry as interest group. Active groups often included associations of pre-existing friends who shared information through real-world connections offline, *i.e.* outside the network space. Although the largest social group nominally comprised 29,626 members, from the activity on the pages it would appear that no more than ~200 members actively engaged in posting fish pictures and video footage.

Images of specimen fish were frequently accompanied by information relating to the location where the specimen was caught, including nearest city, depth, grouper weight and the time of the dive. In the group with 29,626 members, it was compulsory for members to provide a description of the fish, the fishing method used, the location, the depth, diving method and the time, in addition to keeping postings strictly related to fishing and hunting. Location was often subsequently omitted from more recent postings, as several members openly voiced their fears that advertising their catch rate and size of specimens in specified

areas might lead to increased blast / dynamite fishing activity, thereby posing dangers to recreational divers.

Other Facebook groups did not show details relating to their members or provide information regarding fishing / catch locations. Sometimes this information was derived *post hoc* by following particular members and subsequently locating a city. Postings where the location of the fish was unknown were not included within the study.

### ***Individual Facebook pages and social networks***

From 200 Facebook users that were followed, most chose privacy settings that allowed access to their postings only by friends, but since they often posed with dusky grouper in their Facebook profile photos (PPs) it was possible to include them as individuals with an interest in spearfishing. Thirty two timelines with open access were, however, fully accessible. The information gathered from open access Facebook groups often allowed tracking of the fishing activity of other individuals, nominally inaccessible due to their restricted privacy settings. The remaining 168 Facebook users provided regular posts within the spearfishing Facebook groups but they offered no access to their personal Facebook pages. Some Facebook users provided personal information regarding their place of work, age, marital status, residence *etc.* Some of this information was useful in identifying potential fishing activity in waters close to coastal cities, and in neighbouring Tunisia, Egypt Algeria and Morocco. All the spearfishing activity posted on Facebook from Libyan-based groups appeared to involve men, typically aged between 16-40 years old, and to a lesser extent those aged 40-50+.

### ***Spearfishing in Libya***

Spear fishermen reporting catches could be divided into three nominal categories, “professional”, “seasonal” and “recreational / sport”, according to the diving method they used, their catches and the comments made by Facebook members. Diving depths ranged from shallow (ca. 10 m) to deep (ca. 50 m); the size of the dive party varied from solitary dives to groups of seven spear fishermen; the duration of the dive ranged from an hour up to eight hours. Weather-permitting, the spear fishermen operated all year round, with certain operators using dive computers and professional underwater cameras to document their dive activity. It was often mentioned in comments that for diving from December to February, the water was particularly cold and that grouper were seldom seen. In March, however, the spear fishermen commented on the increased sightings of dusky grouper. Most postings including appended images used photographs captured using mobile phones.

### ***Frequency of posting for fishing activity***

Providing a precise estimate of fishing activity is difficult given the central issue of access to personal Facebook pages. The available evidence suggests, however, that recreational spearfishing activity increased on Thursday and Friday of each week, which are typical rest days in Libya as they comprise the national weekend. While there appears to be daily spearfishing activity by professional fishermen, the flow of information on Facebook from recreational fishermen is more constant than from the professionals.

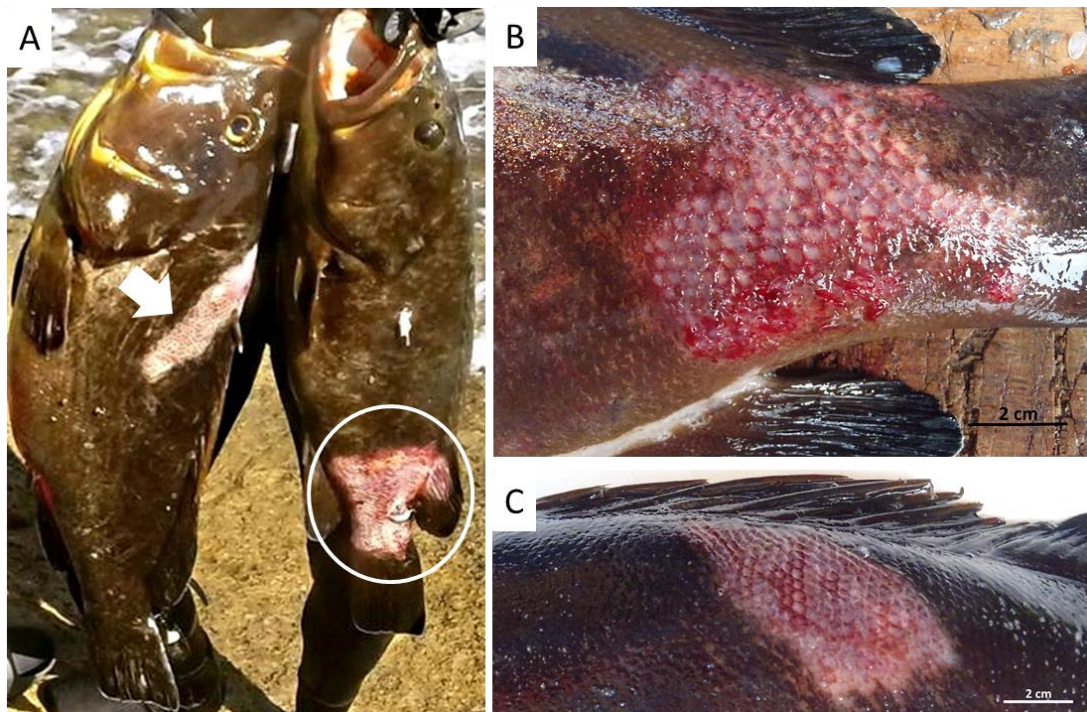
### ***Dusky grouper skin lesions seen on Facebook pages***

Within the timeframe set for this study, *i.e.* December 2011-December 2015, the commentaries and photographs of grouper and spearfishing activity shared between networks of members and friends could be followed, and by doing so, the prevalence of skin lesions in dusky grouper captured from populations along the Libyan coastline could be estimated.

The earliest record of lesions documented on Facebook, appears to be from a picture of dusky grouper caught in the area of El Alose taken in January 2008, which was posted in 2013 and showed that two (>60 cm TL) of the three dusky grouper portrayed had evident skin lesions. From a total of 387 dusky grouper photographs of fish measuring between 20-100 cm TL that were posted on Facebook, 25 fish obtained from 11 separate images, were subsequently discarded as they were not appropriate for inclusion within the analysis, either because the images did not show the skin condition clearly or it was not possible to estimate the size of the fish. Of the analysable 362 fish, 156 fish ranging in size between 20-39.5 cm TL showed no observable lesions, while 57 of the remaining 206 fish, ranging in size from 40 to ~100 cm in total length, showed evident skin lesions, giving an overall prevalence of 15.75% (**Table. 1**). These fish were caught in water depths ranging from a few metres to up to 50 m. From video footage posted on Facebook and YouTube of four separate dusky grouper from the west (Tajoura and Misratah) and centre of Libya (Zwetina), three of the fish can be seen to have skin lesions posterior to the eye, while one has relatively extensive skin lesions below the dorsal fin. The swimming behaviour of all five videoed dusky grouper appears to be unaffected.

**Table 1.** Relationship between the size of dusky grouper, *Epinephalus marginatus*, (*i.e.* total length in cm) and the prevalence of skin lesions on 362 analysable specimens landed in Libyan coastal waters between December 2011 and 2015. After assessment and exclusion of unreliable images (n=25), only data on 362 of the 387 dusky grouper captured were used for analysis. (\*) 3 fish from El Alose were shown in an image, of which 2 fish had skin lesions. These fish were captured in 2008 but pictures were only posted in 2013 with comments on fishing date and area.

Total length (cm)	20-29.9	30-39.9	40-49.9	50-59.9	>60	Total
Total no. fish	31	125	122	54	30	362
Total fish with lesions	0	0	26	20	11*	57



**Figure 1.** Pictures of dusky grouper, *Epinephalus marginatus*, with skin lesions as posted on a private Facebook page (A), and sampled from a local fish market (B and C). (A) Two dusky grouper caught by spearfishing showing skin lesions below the dorsal fin (arrow) and caudal peduncle (circle). Note the similarity in the morphological presentation of the lesions with (B) a dusky grouper with a skin lesion affecting the caudal peduncle and (C) the skin lesion below the dorsal fin. *Image A used with the permission of Mr. El Shagmani.*

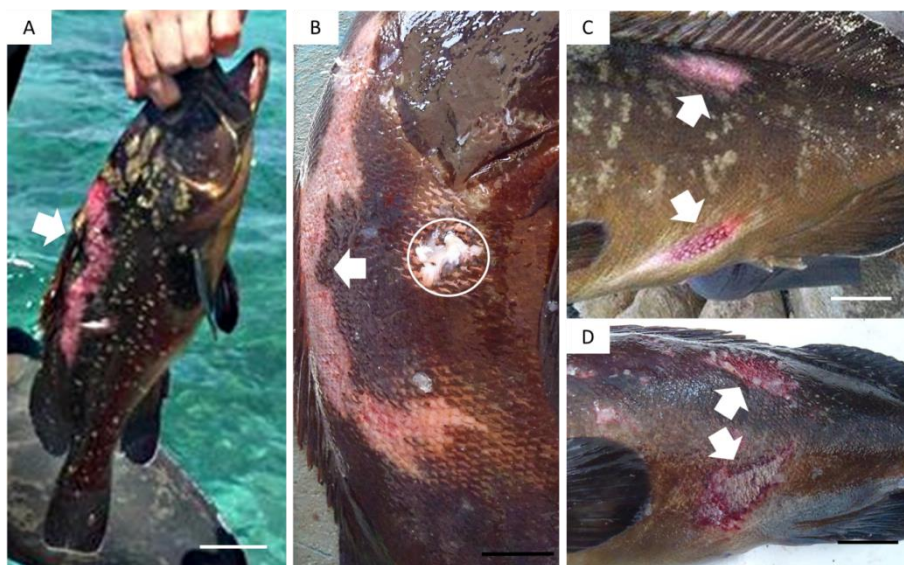
Observed lesions were located posterior to the eye, below the dorsal fin, around the abdomen, on the caudal peduncle and around the cloaca. **Figures 1-3** show a comparison of the lesions described in Rizgalla *et al.* (2016) with those apparent from images posted on Facebook, showing similarities in the gross morphologies observed. These images include healed and severe lesions posterior to the eye, acute lesions affecting the caudal peduncle, acute lesions affecting the flanks and healing lesions below the dorsal fin. In addition, a DGD healing lesion affecting the isthmus below the jaw is compared to an image posted on Facebook of an acute lesion similarly affecting the isthmus (Figure 4). From the posted images, apart from the dusky grouper, no other fish species caught at the same time were seen to be affected by skin lesions. Fish showing no sign of lesions included members of the families Carangidae, Mugilidae, Mullidae, Serranidae and Sparidae.

#### ***Epidemiology and geographical distribution of dusky grouper showing lesions***

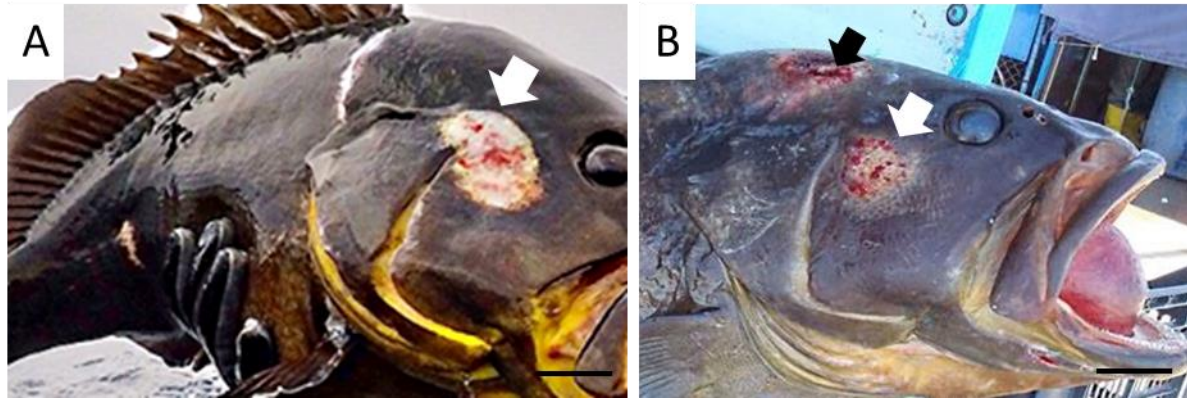
Some captured images were associated with information about the location of capture. In addition, a number of uploaded pictures included the time and date on the photograph. Some of the spear fishermen on Facebook had the location option switched on, actively broadcasting where they were and documenting their precise location at the time they submitted their posting. Thus it was possible to map the prevalence of grouper with skin lesions to coastal cities. The current study found dusky grouper with lesions in the vicinity of 19 of the 23 Libyan coastal cities from which Facebook postings were made (**see Figure 5 and Table 2**). The 26 dusky grouper caught in the waters off Athrun, Ras Al Helal, Karsa, and Derna ranging in size from 40-70 cm TL, however, displayed no observable lesions.



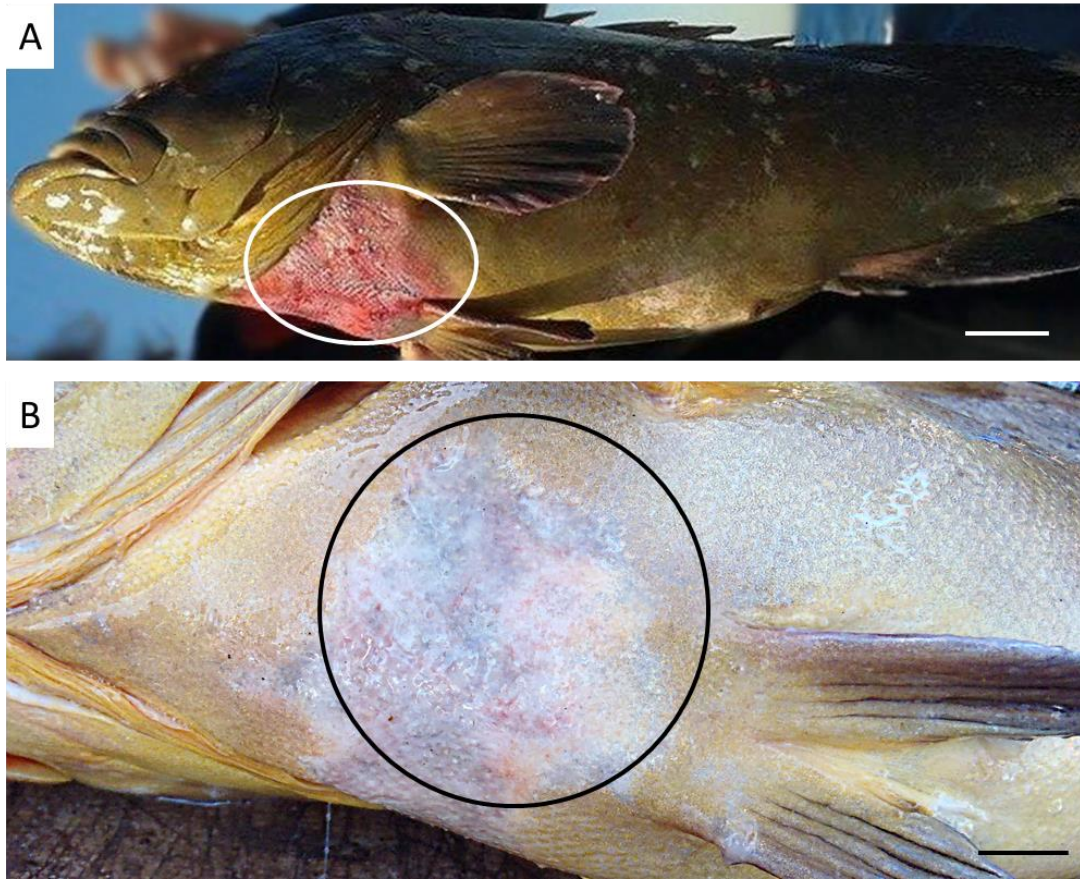
The prevalence of skin lesions for individual cities was calculated only from cities with entries of 10 fish or more, thus only entries from Tajoura, Misratah, Sirt, Tripoli and Benghazi were used (Figures 5 and 6). Dusky grouper pictures posted by Facebook members from Tajoura showed the highest prevalence of lesions with 25% skin lesions, followed by Misratah 20%, Sirt with 18.5 %, the capital Tripoli with 15.5 % and Benghazi with 7.6%. The reasons for such variability remain unclear (see Figure 6 and Table 2).



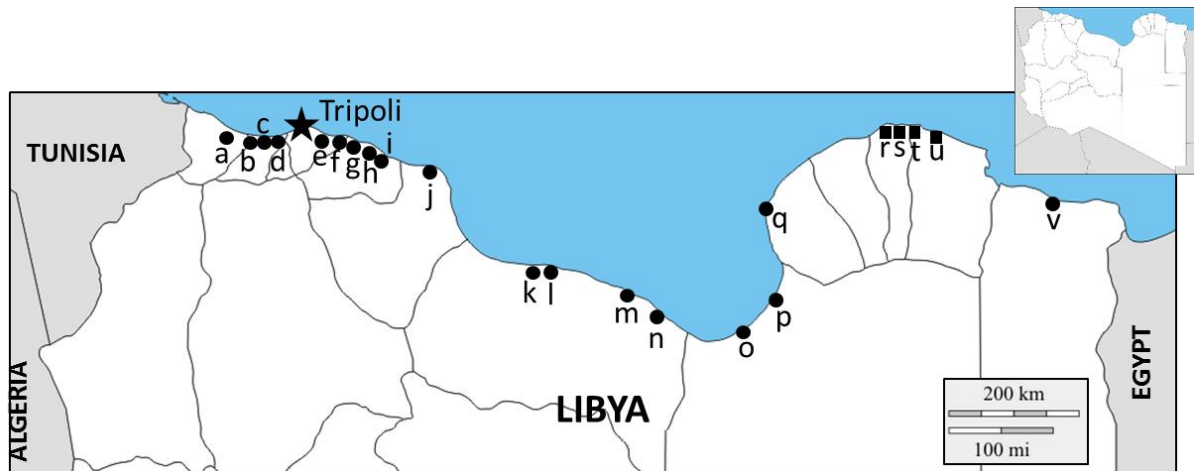
**Figure 2.** (A) Dusky grouper, *Epinephalus marginatus*, posted on a Facebook group (arrow) showing severe lesions. (B) Note the almost identical skin lesion affecting a dusky grouper sampled from a fish market in Tripoli that had been caught by spearfishing, evident from the penetration wound caused by the harpoon (circle) and showing a fused extensive skin lesion below the dorsal fin at a healing stage (arrow). (C) Dusky grouper posted on a Facebook group page with one lesion below the dorsal fin and one on the abdomen. (D) Dusky grouper sampled from a fish market in Tripoli showing multiple lesions similar to those in (C) - one below the dorsal fin and one on the abdomen (arrow). Note the almost identical position of the lesions. Scale bar: A & C & D = 2 cm; B = 4 cm. Image A used with the permission of Mr. Fozi and image C used with the permission of the Facebook group Libyan Youth.



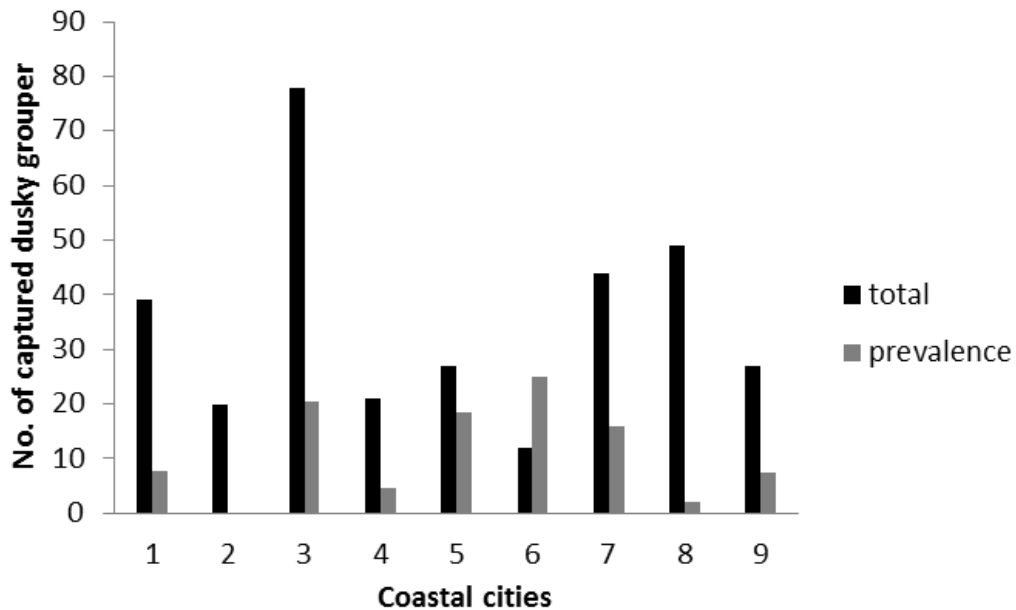
**Figure 3.** (A) Dusky grouper *Epinephalus marginatus* caught by spearfishing as posted on Facebook with a healing lesion posterior to the eye. (B) Dusky grouper picture taken from a fish market in Tripoli showing multifocal skin lesions, one posterior to the eye (white arrow) and one on the head (black arrow). Scale bars: A & B = 3 cm. *Image A used with the permission of Mr. El Shagmani.*



**Figure 4.** (A) Picture of a dusky grouper, *Epinephalus marginatus*, showing severe skin lesions affecting the isthmus of the jaw. (B) A healed skin lesion on the jaw isthmus of a dusky grouper sampled from a fish market in Tripoli. Note the darker discolouration against the background typical of a healed lesion. Scale bars: A = 5 cm; B = 2 cm. *Image A courtesy Mr. Ben Salem.*



**Figure 5.** Records of the occurrence and prevalence (%) of skin lesions on dusky grouper, *Epinephalus marginatus*, caught by spearfishing in Libyan coastal waters obtained from an analysis of Facebook™ image postings between December 2011-December 2015. Cities marked by a black circle denote capture regions where lesions were seen on fish, while cities denoted by a black square represent regions where no lesions were seen on captured fish. Lesion prevalence is only estimated for capture reports of 10 or more fish. Tripoli /Nadi Bahri 15.9%. Key: a = Sabrata 4.7%; b = Surman; c = Mutrod; d = Zawia 7.4 % ; e = Tajoura 25%; f = Garaboli; g = El Alose; h = Celine; i = Al Khums; j = Misratah 20.5 %; k = Sirt 18.5%; l =Sulatan ; m = Ben Jawad; n = Ra’s Lanufn; o = Al Burayqah; p = Zwetina; q = Benghazi 7.6 %; r = Ras Al Helal; s = Athrun; t = Karsa 0%; u = Derna 0%; and, v = Tobruk.



**Figure 6.** The prevalence of skin lesions on dusky grouper, *Epinephalus marginatus*, caught in the coastal waters of Libya during the study period and posted on Facebook. Only cities where 10 fish or more were landed are shown. Fish are categorised according to the nearest major town or city to the capture site. Total fish number is indicated by the black bars and the prevalence of skin lesions by the grey bars. Key: 1 = Benghazi 7.6 %; 2 = Karsa 0%; 3 = Misratah 20.5 %; 4 = Sabrata 4.7%; 5 = Sirt 18.5%; 6= Tajoura 25%; 7 =Tripoli /Nadi Bahri 15.9%; 8 = Tobruk; 9 = Zawia 7.4 %.

### **Facebook members' reactions to dusky grouper skin lesions**

In Libya, it is widely believed by the fishermen and divers that observable lesions can be attributed to the attachment and feeding activity of remoras, *Remora remora* (L.) (Echeneidae), known locally as the "Golfat". Hence, although the skins lesions do not go unnoticed, they do not generally elicit concern within the Facebook community. There has, however, been some limited speculation regarding the cause of the lesions. In one post written in 2014 and then re-posted in 2015, it was suggested that the cause of the lesions

was due to viral nervous necrosis resulting in a loss of equilibrium and with the resulting physical damage leading to secondary bacterial infection. A second post in October 2014, suggested that the lesions were due to a fungal infection and cautioned readers not to eat “infected” fish, while other postings suggested cutting out infected areas *etc.*

Of the relevant videos available on YouTube ( $n = 3$ ),  $2/3$  were posted by the same group members who were active on Facebook and in  $2/3$  cases, the same video footage had already been posted on their private Facebook pages or within the Facebook common interest group.

**Table 2.** The number of dusky grouper, *Epinephalus marginatus*, with and without skin lesions, caught in the coastal waters of Libya. Fish are categorised according to the nearest major town or city to the capture site. DG = dusky grouper.

<b>City</b>	<b>Lesions/ DG examined</b>	<b>Prevalence %</b>
Athrun	0/3	0
Al- Khums	2/6	33.3
Al Burayqah	1/7	14.2
Benghazi	5/39	7.6
Jadabia	0/1	0
Ben Jawad	4/8	50
Celine (Villa Seleen)	1/1	100
El Alose	2/3	66.6
Garaboli	3/7	42.8
Karsa / Derna	0/20	0
Misratah	16/78	20.5
Mutrod	1/1	100
Ra's Lanufn	1/2	50
Ras Al Helal	0/3	0
Sabrata	1/21	4.7
Sirt	5/27	18.5
Sulatan	1/1	100
Surman	1/1	100
Tajoura	3/10	25
Tripoli / Nadi Bahri	7/44	15.9
Tobruk	1/49	2
Zawia	2/27	7.4
Zwetina	2/2	0

*Spearfishing in neighbouring countries and the prevalence of dusky grouper skin lesions*

Several pages from similar interest groups posting pictures of dusky grouper were found in Tunisia (2), Algeria (5), Egypt (1), Turkey (1), Italy (1) and Spain (1). While most of the dusky grouper displayed were 60-80 cm TL, no lesions were seen except for two fish measuring >70 cm TL that were spearfished in Algeria and one in Turkey measuring 70 cm, which had evident lesions close to the cloaca and on the caudal peduncle (pictures not shown).

## Discussion

This study has demonstrated that social media and other allied digital resources can be used as a valuable supplementary source of epidemiological data for examining the health of fisheries. This agrees with the findings of previous authors reporting on findings in other sectors, and who have also recognised the utility of online social media networks for disease surveillance. For example, Corley, Cook, Mikler & Singh (2010) demonstrated strong correlations between posted blogs reporting flu symptoms and CDC ILI surveillance data for influenza epidemics.

Assessing the population size and health of wild fish populations is challenging and problematic even under optimal conditions (Peeler, Murray, Thebault, Brun, Giovaninni & Thrush 2007). From the images of 362 separate dusky grouper used in this study, 57 fish landed in waters close to 19 Libyan cities were found to have skin lesions while 26 dusky grouper caught in the waters off Athrun, Ras Al Helal, Karsa, and Derna, had no observable lesions. These latter fish were captured at the same time as dusky grouper with lesions were landed elsewhere in Libyan waters and were of similar sizes. The reasons why no fish with lesions were observed from these areas are not clear and it may be either that there is an absence of lesions on fish in this area or that fishermen in this region are selective about what they post or capture. The accurate estimation of prevalence is further constrained by small sample sizes for any given area. More accurate estimation therefore requires further investigation including direct contact with Facebook users to enquire whether dusky grouper with skin lesions are seen in their area and whether individuals might be prepared to provide images for assessment. The digital domain can offer a rich repository of visual material (Vilnai-Yavetz & Tifferet 2015), which can be important as visual material is



considered a key resource in describing and characterising skin lesions affecting fish (Peeler, Ryder, Thrush, Mewett, Hulland & Feist 2014), with use of images avoiding errors inherent in purely verbal descriptions. When the morphology of the skin lesions in the pictures posted on Facebook are compared with the DGD skin lesions described in Rizgalla *et al.* (2016), there are close similarities in their gross morphologies, potentially indicative of common pathology / aetiology. Further similarities between the two datasets reside in the size of fish that are affected by lesions, *i.e.* 42 cm+ TL in Rizgalla *et al.* (2016) and >40 cm TL from the images posted on Facebook. In both cases the only species that appears to be affected is dusky grouper and observed lesions were present on landed fish throughout the year. While the DGD lesions are often severe, these do not appear to impair feeding (Rizgalla *et al.* 2016) or normal swimming behaviour (video footage posted on Facebook).

The small number of postings showing dusky grouper with lesions, for fish caught in Algerian and Turkish waters require further investigation to determine their significance and the possible wider distribution of DGD elsewhere in the Mediterranean.

The popularity and commercial value of dusky grouper as a target for spearfishing (Reñones *et al.* 2007) contribute, among other factors, to the frequency and quality of the information that is posted on social network sites. This is evident from the competitive nature of recreational spearfishing within and between different interest groups as seen from the largest Facebook group of over 29,626 members. Members from a broad geographical distribution regularly reporting catches and supplying photographs, provide a unique resource for observing visible markers of fish health with associated metadata, including details relating to the site / conditions of capture and the size of fish. In the absence of this social network site, this information would be unavailable unless gathered from those

individuals willing to declare their participation through the use of surveys (Mann, Scott, Mann-Lang, Brouwer, Lamberth, Sauer & Erasmus 1997; Morales-Nin *et al.* 2005).

Spearfishing is a relatively inexpensive activity requiring simple equipment (*i.e.* diving fins, a mask and a trigger harpoon). This may in part contribute to its popularity across divergent social strata. From the current study, spearfishing in Libya is predominantly practiced by the younger male population, 16-40 years old, drawn from diverse economic and social backgrounds and, to lesser degree, by men aged 40-50. A similar observation was made by Morales-Nin *et al.* (2005) who noted that 90% of the recreational fishermen around the island of Majorca were men with a mean age of  $46 \pm 2$  years. No female participation in the Libyan spearfishing groups is evidenced from Facebook or from the YouTube postings. In terms of widening the social network web (Boyd & Ellison 2007), Facebook friendships in a spearfishing context could sometimes be formed between people more than 1,000 km apart and crossing borders into the neighbouring countries of Tunisia, Egypt, Algeria and Morocco.

With over 200 identified Facebook members indicating that they spearfish as a regular activity, it is clear that this fishing method is widely practiced and is capable of exerting increased pressure on an already vulnerable coastal fish species. Although spearfishing is banned in Marine Protected Areas (MPA) within the waters of some Mediterranean countries (Coll, Garcia-Rubies, Moranta, Stefanni & Morales-Nin 1999), spearfishing is common throughout the Mediterranean Sea. Similarly, spearfishing in Libya is an uncontrolled fishing practice as it is elsewhere in the Mediterranean. More information is needed to assess levels and impact of recreational fishing (Camilleri, Carpentieri, Cervantes, Charilaou, Darmanin, Dimech, Guijarro, Moguedet, Perez Gil, Vassiliades, Vassilopoulou &

Vigneau 2007), in order to improve management practices and conservation of protected species.

### ***Study constraints and limitations***

The passively generated data derived from Facebook postings, while providing a considerable improvement on the pre-existing total lack of data, nevertheless suffer from a range of problems including a lack of consistency given the sporadic and unstructured provision of information, an unknown fishing effort and a high probability of unshared data. As it is not possible to see the entire body surface in each photograph, it is highly likely that the actual prevalence of skin lesions in dusky grouper is higher than the estimated prevalence provided by this study. The lack of parallel samples for histopathological evaluation prevents direct investigation and characterisation of lesions and the potential for determining their aetiology.

Spearfishermen may participate and post updates on one or more social network sites and so caution must also be exercised in ensuring that the same fish is not double counted when it appears on different sites. Through the analysis of photographs in the current study, the authors were aware that on several occasions the same fish pictures were sometimes re-posted on different sites and sometimes months apart. To minimise errors in determining the prevalence of lesions, cross-checking is required, involving the initiation of searches at the time at which the individual(s) activated their accounts, and then the checking of all subsequent postings.

Some Facebook users have a “friends only” setting to ensure privacy and hence access to these pictures was not possible. Within certain open groups, pictures of fish can be accessed but occasionally the source/author of the photograph is anonymous. To address these issues, information can be obtained by reading the comments linked to the photographs or by following those individuals recording a “like” vote for the image to their own Facebook pages. By employing this strategy, it was possible to identify some of the original authors/publishers of the work and to subsequently determine the location of capture. Although this method was successful on this occasion, it proved to be an extremely time-consuming task.

While the information posted on Facebook may not reflect the actual fishing activity of each individual, there may be considerable potential to form a network of people potentially willing to join monitoring programs and to take part in controlled surveys. Such people are commonly described as “citizen scientists” and comprise individuals volunteering to collect and / or process data relevant to scientific enquiry (Silvertown 2009). Volunteers might be recruited using the Facebook groups and profiles already identified in the current study as a basis, in order to create a Facebook network which could be used to provide disease surveillance information.

In conclusion, this study has shown that under conditions where a visible pathological marker is present in photographs, social network sites may be employed to conduct preliminary epidemiological studies in situations where other sampling or survey strategies may be difficult or impossible. In data collection terms, such a survey method can also be extremely cost-effective although it may be manpower-intensive. While mining data from these social network sites represents an innovative approach to the collection of data that

might otherwise be regarded as inaccessible, it is important to ensure that, although the information is already in the public domain, the privacy and anonymity of participants on each website are not infringed and that confidentiality is upheld. There are, however, limitations to the usefulness of these sites, as is the case for conventional survey methods, in that the information available is limited to the users' interest in specific fields and subjects, and their willingness to cooperate with researchers.

The information posted on social network sites and allied sources of information and media represents an extensive and varied resource that can support epidemiological studies in particular contexts. These sites increase the number of observers of certain conditions, increasing the likelihood of obtaining data on short-lived events, *e.g.* fish stranding / mortality events, over wider areas that, in most cases, are not possible to access within the remit of funded research. The current study, for example, demonstrates that information relating to the incidence of skin lesions on dusky grouper, an endangered species, over an area extending the entire 1,770 km coastline of Libya, during a period of civil and political unrest has been possible by mining data posted on a range of social network sites.

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