REVIEW ARTICLE

Worldwide recreational fish feeding: a review on ecological impacts

Felipe Monteiro Gomes de Mattos,[a*] Thamasak Yeemin[a]

[a]Marine Biodiversity Research Group, Department of Biology, Faculty of Science, Ramkhamhaeng University, Huamark, Bangkok 10240, Thailand

**Corresponding author: felipemgmattos@hotmail.com*

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Abstract. Fish feeding is one of the most sought activities among coastal tourism in coral reef areas. This worldwide spread action affects especially tropical countries, spreading to warm temperate areas. We try to compare the ecological effects of fish feeding in different areas of the world. An extensive literature research was conducted with later appropriate filtering to include only those surveys focused on the fishes and on "easy access" tourism. Altogether studies identified around 56 reef fish species feeding on human provided food. The damselfish genus *Abudefduf* is the most cited regarding abundance and frequency of feeding, and followed mainly by other omnivorous species and benthic invertebrate feeders. Records indicate that unnatural aggregations form as a result of food provisioning, and remain even after tourists leave the area. In addition, aggressive behavior and changes in movement or diet activity patterns were also registered. Favoring growth in generalist abundance can lead to lower local diversity and increase the homogeneity of the community. At the same time, maintaining unnatural high abundance of predators, as well as shifting their activity to day time, might cause the decrease in prey populations. The ecological effects of recreational fish feeding are subtle and harder to point than physiological or behavioral, and its future impacts are equally hard to predict without appropriated studies.

Keywords: Reef fish, Tourism, Food provisioning, Coral reefs.

1. Introduction

Humans interest to interact with wildlife probably date from the beginning of our times. Nowadays, urban development induces millions of people to seek for ecotourism related activities worldwide (Gössling 1999; Bellan and Bellan-Santini 2000). Coastal tourism is among the most sought and fastest growing economic activities (Wood 2001; Spalding et al. 2017), especially, in tropical countries. Some environmentalists and researchers often point ecotourism as a sustainable answer to areas before degraded and over exploited. Although it is undeniable that non-extractive activities are easier to manage in conservation matters, unsupervised tourism can severely impact marine areas, especially, susceptible environments like coral reefs (Davenport and Davenport 2006; Lamb et al. 2014). In addition, "untouched" natural areas such as MPAs, gradually become more attractive to tourists (Badalamenti et al. 2000).

Non-consumptive uses in coastal areas include a wide range of activities that can vary from animal watching to directly interacting with it (Duffus and Dearden 1990; Brander et al. 2007). In sandy beaches and coral reefs, one of the main attractions to generate human-animal interaction is the artificial feeding, where tourists or guides provide food to attract the fishes. This activity is commonly seen around the world (Orams 2002; Patroni et al. 2018). Records of impacts range from fish health (bad nutrition, stomach ulcers and rapid parasite spreading), behavior changes (shift in activity patterns, and human oriented behavior), to ecological impacts at community levels (unnatural aggregations and movement patterns), although this last one is still hardly discussed as the impacts are indirect and not so easily observed (Orams 2002; Patroni et al. 2018).

Since several papers describe responses that might be linked to broader ecological impacts (cited above), our goal was to review and summarize how reef fish communities react to recreational feeding at different locations around the world. Pointing differences and resemblances, as well as discussing further indirect ecological effects that might arise from this activity.

2. Materials and Methods

An extensive bibliography survey was done during October 2018, using the keywords "Recreational fish feeding", "Tourism fish feeding", "Fish food provisioning" as main terms. Additionally, more generic or derived terms were used to complete the search. Secondarily we used crossed references from the found papers to search for different studies, missed on the first phase. Lastly we filtered the papers found, focusing on: (1) surveys done directly on fishes, excluding human focused surveys, like questionnaires; (2) studies that aimed on "easy access" coastal tourism, such as bathing, snorkeling and quick boat trips *i.e.* avoiding surveys related to scuba diving (which excluded most researches done in Elasmobranchii), for in our understanding, the last is somewhat easier to manage. We didn't include previous review papers in our database, as the focus was to bring a discussion directly related to the results found in primary surveys.

3. Results

A total of 60 papers discuss the impacts of recreational fish feeding. Surveys were done in over 20 different countries, being Perrine (1989) the pioneer in this subject. However, 46 of those are not applicable for our discussion either for involving scuba diving, for being a questionnaire based social research, or previous reviews. In the end, only 14 papers were applied to our purposes and included in the database (Table 1). Publications from Brazil and Italy are the laregest numbers, with 5 and 3 papers published, respectively. Although the latter had only one studied area, while the former had its surveys spread into 5 different localities (2 papers on overlapping areas and one paper covers 2 different locations).

The 14 papers conjoint database results in 56 fish species (55 Actinopterygii and 1 Elasmobranchii) recorded for feeding on human-provided food, from a total of over 170 species registered to inhabit the respective study areas. However, the majority of these 56 taxa appeared to be occasional records, with low abundance (often less than 1%) and frequency.

Twenty-four species from 12 families are described as active feeders (Table 2), according to the following criteria: (1) To be described by the authors among the most active or most frequent recorded species; (2) Showing a fast response to the food provisioned (or significantly faster than the remaining species) and (3) Having abundances higher than usually found in natural conditions (either based on provided data or compared to previous literature). The Pomacentridae, Labridae and Sparidae Families show higher richness with 6, 4 and 3 species, respectively (Table 2).

Most species in the above cited group show a generalist diet, in majority, fishes that feed on small benthic invertebrates or those classified as omnivorous (8 species each), carnivores represented by 4 species and herbivores by the remaining 4 (Table 1). Species in the first two groups are repeatedly reported as those with higher abundances and frequencies, *e.g. Abudefduf saxatilis* and *Haemulon aurolineatum* in Brazil; *Myxus elongatus* in Australia; *Oblada melanura* and *Thalassoma pavo* in Italy and *Abudefduf vaigiensis*, *A. sexfasciatus* and *Thalassoma lunare* in Kenya and Thailand.

Albeit the different approaches, all the 14 papers record fish densities above the usual number, ranging from *2x* until *5x* the abundance in natural circumstances. Authors often describe unnatural aggregations by species that naturally don't form big schools, e.g. *Lethrinus nebulosus*, *Thalassoma pavo*, *Hipanus americanus* and *Abudefduf saxatilis* (in Ref. 16 where the mean abundance reached more than 500 individuals). In addition, several of the studies report how those aggregations don't cease to exist after the food is no longer provisioned or humans are no longer present, in fact, fishes easily learn to predict time and days when tourists will arrive (Milazzo et al. 2006; Chateau and Wantiez 2008; Feitosa et al. 2012).

Besides the behavior described above, other ethological effects are commonly observed, such as the shift in natural diet activity. The Spangled emperor (*L. nebulosus*) and the Tomtate (*H. aurolineatum*) are nocturnal species that feed on benthic invertebrates usually in the sandy areas surrounding the reefs (Darcy 1983; Lieske and Myers 2001; Pereira and Ferreira 2013). However, during the tourist recreational feeding, both species have been recorded as active feeders at day time. Lastly, excessive aggression between individuals was recorded in at least 4 surveys to be present not only when the food was provisioned, but also described to remain as an after effect of the competition between a huge number of fishes for a single food source (Milazzo et al. 2006; Hémery and McClanahan 2007; Medeiros et al. 2007; Brookhouse et al. 2013).

Table 1. List of papers on recreational fish feeding, focusing on fish assemblages and fed by coastal tourist activities, separated by surveyed country.

Country	Reference
Australia	Brookhouse et al. 2013; Sweatman 1996
Brazil	Albuquerque et al. 2015; Feitosa et al. 2012; Ilarri et al. 2008; Medeiros et al. 2007; Paula et al. 2018
Cayman Islands	Corcoran et al. 2013
Italy	Milazzo et al. 2005; Milazzo et al. 2006; Milazzo 2011
Kenya	Hémery and McClanahan 2005
New Caledonia	Chateau and Wantiez 2008
Thailand	Sa-nguansil et al. 2017

Table 2. List of species registered actively feeding on human provided food. Trophic categories: Carnivore (CA), Herbivore (HE), Invertebrate feeders (IF), Omnivore (OM), Planktivore (PLK).

Family	Species	Distribution	Trophic category	Paper
Carangidae	*Pseudocaranx dentex* (Bloch & Schneider, 1801)	Circuntropical	PLK / IF	Brookhouse *et al* 2013
Carangidae	*Seriola lalandi* Valenciennes, 1833	Circuntropical	CA	Brookhouse *et al* 2013
Kyphosidae	*Kyphosus sydneyanus* (Günther, 1886)	South West Pacific	HE	Brookhouse *et al* 2013
Mugilidae	*Myxus elongates* Günther, 1861	South West Pacific	OM	Brookhouse *et al* 2013
Lethrinidae	*Lethrinus nebulosus* (Forsskål, 1775)	Indo-Pacific	CA	Brookhouse *et al* 2013; Sweatman *et al* 1996; Chateau & Wantiez 2008
Lutjanidae	*Lutjanus bohar* (Forsskål, 1775)	Indo-Pacific	CA	Sweatman 1996
Pomacentridae	*Abudefduf sparoides* (Lacepède, 1801)	Indian	OM	Hémery and McClanahan 2005
Pomacentridae	*Abudefduf sexfasciatus* (Quoy & Gaimard, 1825)	Indo-Pacific	OM	Hémery and McClanahan 2005; Sa-nguansil 2017
Pomacentridae	*Abudefduf bengalensis* (Bloch, 1787)	Indo-Pacific	OM	Sa-nguansil *et al* 2017
Pomacentridae	*Abudefduf vaigiensis* (Quoy & Gaimard, 1825)	Indo-Pacific	OM	Sa-nguansil *et al* 2017
Siganidae	*Siganus canaliculatus* (Park, 1797)	Indo-Pacific	HE	Sa-nguansil *et al* 2017
Siganidae	*Siganus javus* (Linnaeus, 1766)	Indo-Pacific	HE	Sa-nguansil *et al* 2017
Labridae	*Thalassoma lunare* (Linnaeus, 1758)	Indo-Pacific	IF	Sa-nguansil *et al* 2017
Pomacentridae	*Chromis chromis* (Linnaeus, 1758)	Mediterranean	PLK / IF	Milazzo *et al* 2005, 2006; Milazzo 2011

Table 2. (Cont.)

Family	Species	Distribution	Trophic category	Paper
Labridae	*Coris julis* (Linnaeus, 1758)	Mediterranean	IF	Milazzo *et al* 2005, 2006; Milazzo 2011
Sparidae	*Oblada melanura* (Linnaeus, 1758)	Mediterranean	OM	Milazzo *et al* 2005, 2006; Milazzo 2011
Sparidae	*Sarpa salpa* (Linnaeus, 1758)	Mediterranean	IF / HE	Milazzo *et al* 2005, 2006; Milazzo 2011
Sparidae	*Spondyliosoma cantharus* (Linnaeus, 1758)	Mediterranean	OM	Milazzo *et al* 2005, 2006; Milazzo 2011
Labridae	*Thalassoma pavo* (Linnaeus, 1758)	Mediterranean	IF	Milazzo *et al* 2005, 2006; Milazzo 2011
Dasyatidae	*Hypanus americanus* (Hildebrand & Schroeder, 1928)	West Atlantic	CA	Corcoran *et al* 2013
Pomacentridae	*Abudefduf saxatilis* (Linnaeus, 1758)	West Atlantic	OM	Medeiros *et al* 2007/ Ilarri *et al* 2008 / Feitosa *et al* 2012 / Albuquerque et al 2015 / Paula *et al* 2018
Haemulidae	*Haemulon aurolineatum* Cuvier, 1830	West Atlantic	IF	Feitosa *et al* 2012 / Paula *et al* 2018
Haemulidae	*Haemulon parra* (Desmarest, 1823)	West Atlantic	IF	Ilarri *et al* 2008
Labridae	*Halichoeres poeyi* (Steindachner, 1867)	West Atlantic	IF	Medeiros *et al* 2007

4. Discussion

Comparison between the 24 taxa directly attracted by recreational feeding and the remaining community reveals some resemblances between surveys. Countries where the study focus was the whole fish assemblage (i.e. Brazil, Italy, Kenya, Thailand and Australia) and had always an omnivorous species described as mainly attracted, both in abundance and frequency. Specifically, *Abudefduf* spp. seems to be particularly attracted wherever present. Fishes in this genus are omnivorous generalists, often described as opportunists, which swim actively in the water column feeding on plankton usually in small schools, but is also highly attached to the substrate where it feeds on small invertebrates and microalgae (DeLoach and Humann 1999; Lieske and Myers 2001; Allen et al. 2015). The generalist diet, pelagic and schooling behaviors, as well as a natural high frequency in coral reefs, favor species in this genus when an artificial and easy source of food is introduced.

Secondarily, the number of species attracted and actively feeding is noticeably similar between areas, varying from 2 in Kenya to 6 in most countries. A detailed look at fish species by location show even bigger resemblances. In Brazil each single survey identified one or two taxa feeding actively, while in Thailand and Australia each location had from 2 to 4 species frequently attracted. Surprisingly, the temperate habitats of Utica Island in Italy hold a larger number of species approaching humans (12), although this might result from the experimental nature of the survey (see Milazzo et al. 2006). These data indicates that the number of frequently attracted species might not be related with the overall richness of the region. In addition, the small number of taxa recorded per country reveals that recreational feeding might be favoring fewer species at each site.

The above mentioned effect is easily observed when comparisons are made between number of feeders and local richness. The four species recorded in Brazilian waters represent less than 10% of the total richness, which we assume to be between 56 and 70 species (since only 2 papers provided a species list, and assumption was based on location differences). Similarly, in Kenya, 63 taxa were listed by the authors, resulting in only 3% of feeding species. No community composition list was provided by surveys in Australia or Thailand, nevertheless, previous checklists point a total of 481 fish species, for the first, in Lord Howe Island (Allen et al. 1976; Francis and Randall 1993), although this is a total number and doesn't represents only Ned's beach, where the main study took place. Regarding each locality surveyed in Thailand, literature data suggest between 56 and 68 species (at 3 out of 4 sites) (Satapoomin 2000, 2011), resulting in less than 10% active feeders, as well as Brazil. Mediterranean waters hold the greater relative number of attracted species (almost 30%), as the local richness reached only 19 species.

Favoring the abundance of a few species might have impacts yet poorly understood in coral reef ecosystems. Low diversity numbers are positively related with higher relative abundances of few taxa, which directly affect the whole community by competition and predation. Low diversity can also drive to habitat homogeneity, which tends to benefit certain groups (Kassen 2002). The whole consequence in such circumstances is hard and risky to predict, as many variables could change the resulting effects. However, by chance, the final stages of impacts could end up favoring the same dominant species, creating a positive feedback (Olden et al. 2004). This is especially plausible when dominant species are generalists, and often linked to habitat homogeneity (Clavel 2011).

For instance, the 16 species classified as omnivorous or benthic invertebrate feeders have a wide dietary range. The 4 carnivores can also be classified as generalists, since their diet is composed by barely any animal they can feed on. Herbivores are usually classified as specialists, if detritus is not among their food items. However, from the 4 species recorded, only *Kyphosus sydneyanus* can be clearly stated as specialist, feeding mostly on seaweeds (Scott et al. 1974). Both *S. canaliculatus* and *S. javus* are shown to request higher amount of animal protein than other species in the genus (Duray 1998; Yamaguchi et al. 2010). In addition, juveniles of *Sarpa salpa* actively feed on small invertebrates (Bauchot and Hurear 1986), probably as they require a larger amount of protein to supply their growth, shifting to a more herbivore diet with age, as already reported for other species (Ferreira et al. 1998).

Favoring the generalists over specialist species might have long term impacts in coral reef ecosystems. Recent studies already show how the lasts are declining at a higher rate than the first group, due to climate change (Rooney et al. 2004; Büchi and Vuilleumier 2014) and the higher resilience of generalists, capable of feeding on different items according to resource availability (Vázquez and Simberloff 2002). Facilitating the food resources to generalists might give advantages to those few species, impacting on specialists or less dominant groups, susceptible to habitat changes. Rising generalist abundances might impose a dominance shift in natural communities, and increase both intra and inter-specific competition (Tilman 1982; Wilson et al. 2008), and although the first might help to control generalist population, the second, associated with unnatural abundances disfavors specialist species.

When predator populations reach unusual high numbers, the predation pressure over an unprepared prey population might severely impact the ecosystem. Therefore, it is concerned that food provisioning might be attracting too many benthic invertebrate feeders into relatively small areas (this includes the carnivores *L. nebulosus*, *L. bohar* and *Hipanus americanus*), and its impacts have already been described in the Mediterranean (Milazzo et al. 2006). In association, the activity shift of *H. aurolineatum* and *L. nebulosus* during day time, might cause pressures over prey populations that are not yet studied. At last, it's been proved how the composition of resident species alters the settlement success of different trophic groups (Almany 2004), and to date, none of any studies has tried to analyze the settlement patterns in known recreational feeding sites, therefore, those areas might be under a bigger pressure than assumed so far.

Apparently, recreational fish feeding is a common activity worldwide. Although there are still few studies, the physiological and behavioral impacts are clearly observed as already pointed. The ecological effects are, however, still poorly studied and understood, hard to predict and yet concerning. Our review show how the food provisioning attracts mostly generalists, causing unnaturally high densities, movement and activity patterns, that might impact ecological relations such as competition and predation. We recommend that posterior studies should focus on the indirect impacts of recreational fish feeding as well, so this knowledge gap can be fulfilled and possible actions can be taken.

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