**CSIRO** PUBLISHING

*Marine and Freshwater Research*
http://dx.doi.org/10.1071/MF16358

# Local knowledge and awareness on the incipient lionfish invasion in the eastern Mediterranean Sea

*E. Azzurro*[A] *and M. Bariche*[B,C]

[A]Institute for Environmental Protection and Research (ISPRA), Livorno, Piazzale dei Marmi 2, I-57123 Livorno, Italy.
[B]Department of Biology, American University of Beirut, 11-0236, Riad El-Solh, Beirut 1107 2020, Lebanon.
[C]Corresponding author. Email: michel.bariche@aub.edu.lb

**Abstract.** Public participation is increasingly used to both study and manage marine bio-invasions. Here, we outline the use of public surveys to rapidly acquire information on the very first stages of colonisation by the invasive *Pterois miles* in the Mediterranean Sea. Interviews with 105 fishermen, spearfishers and scuba divers in Lebanon provided evidence of a proliferation and rapid expansion of the species, whose presence at the time of the survey was less than that of a true invasion. We also evaluate the role of stakeholders and sea users in responding to this emerging hazard, investigating awareness and willingness to collaborate on managing efforts. These findings showed the potential of local communities to acquire ecological knowledge not available to scientists working alone. This participative approach also consolidates the dialogue and partnership between researchers and stakeholders ameliorating the civil response to time-sensitive conservation issues.

**Additional keywords:** Lessepsian migration, local ecological knowledge, public perceptions.

Received 22 October 2016, accepted 16 January 2017, published online 30 March 2017

## Introduction

Documenting and responding to species invasions requires innovative strategies to account for ecological and societal complexities (Scyphers *et al.* 2015). In this respect, acquiring data directly from the resource users is considered a strategic aspect of both monitoring and managing invasive species (Schüttler *et al.* 2011). This knowledge, often referred to as 'local ecological knowledge' (Anadón *et al.* 2009), is gaining more attention in ecological and fisheries research (Tesfamichael *et al.* 2014). Limited spatial information often challenges conservation efforts against natural threats (Hyder *et al.* 2015) and some of these gaps may be filled by observational approaches performed with the help of local communities (Sagarin and Pauchard 2010). In the Mediterranean Sea, fishermen's ecological knowledge has recently been employed to track the geographical expansion of both native and exotic fish species (Azzurro *et al.* 2011; Boughedir *et al.* 2015) and to fill data gaps in the distribution of exotic species (Elbarassi *et al.* 2014). One of the more recent, highly damaging and most documented marine invasions is that of the Indo-Pacific lionfishes (*Pterois volitans* and *P. miles*), which have rapidly and widely expanded throughout the Caribbean Sea, Gulf of Mexico and the north-western Atlantic during the past two decades (Schofield 2009, 2010; Kulbicki *et al.* 2012). The common lionfish (*P. miles*) was recently recorded in the Mediterranean (Bariche *et al.* 2013; 2015) and immediately begun to be found in several neighbouring areas, raising suspicion of an incipient invasion (Turan *et al.* 2014; Crocetta *et al.* 2015; Dailianis *et al.* 2016; Kletou *et al.* 2016).

Here, we use the local ecological knowledge of various sea users to rapidly assess the status of the common lionfish invasion off the coast of Lebanon (eastern Mediterranean Sea). Our aims were to (1) collect information on the spread of this species at the very early stages of its establishment, and (2) evaluate stakeholder awareness of this emerging environmental issue and their willingness to participate in conservation initiatives.

## Materials and methods

Local fishermen, spearfishers and scuba divers were interviewed during their land activities in seven different locations along the Lebanese coast. These were Tripoli, Enfe, Batroun, Byblos, Dbayeh, Daoura, Ouzaei and Sidon, which represent some of the main fishing ports and marinas in Lebanon (Fig. 1). Interviews were conducted between 1 April 2016 and 11 May 2016. All interviewees were approached with a direct question, namely 'Have you seen the lionfish?' The interview continued with 14 open questions on awareness, local perceptions of potential ecological impacts and willingness to collaborate on controlling this environmental hazard. Once all the interviews were completed, answers where categorised in two to five classes and results were expressed in terms of relative percentage. People who had had direct encounters with the lionfish were

Journal compilation © CSIRO 2017

**Fig. 1.** Geographic locations of single captures or sighting of the common lionfish (*Pterois miles*) reported by $n = 73$ fishermen and divers in Lebanon during the years 2014–2016. (Point coordinates are given in Table S1, available as Supplementary material for this paper.)

asked to indicate geographical location for sightings or captures of the species on Google Earth's interface. This information was later translated into geographical coordinates and imported to QGIS 2.12.1-Lyon (Franklin Street, Boston, MA, USA).

## Results

In total, 105 sea users (5 women and 100 men) ranging from 17 to 75 years of age were interviewed. Respondents were mostly local fishermen operating with trammel nets (63.2%); scuba divers (31.1%) and spearfishers (5.6%). Of the 105 respondents, 30.5% had never captured or observed the lionfish in Lebanon, whereas the remaining 69.5% reported direct interactions with this species. Perceptions on key aspects of this incipient invasion are shown in Fig. 2. In most cases (91.7%), the abundance of the lionfish was indicated as abundance Class 1 (i.e. observed or captured once in 1 year), whereas five scuba divers and one spearfisher reported multiple sightings of this species within the past year (abundance Class 2). Most respondents perceived the numerical abundance of this population as 'increasing', whereas only four fishermen (3.8%) thought the population was stable. In most of the cases (92.3%), lionfish were reported as solitary individuals, and in the other encounters, a maximum of three individuals were observed together. Two professional fishermen reported the sighting of juveniles.

Respondents indicated the exact locations of a total of 151 sightings or captures of the lionfish along the Lebanese coast. These are shown in Fig. 1 and were generally concentrated around interview areas. Both fishermen and divers easily

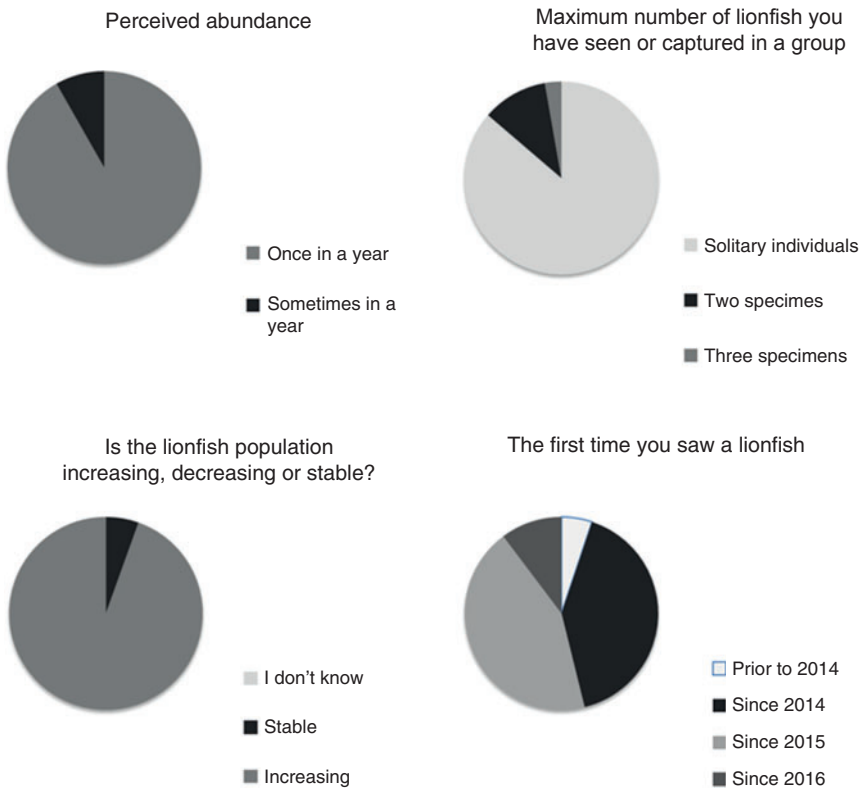


**Fig. 2.** Local ecological knowledge questions and percentage distribution of related answers for 73 respondents. Only those people having direct encounters with the lionfish were considered.

remembered the exact location of these encounters, because they corresponded to sites they regularly used for their activities. Fishes were mainly spotted close to rocky habitats, at depths of 20–40 m and observed or captured both during the day and at night.

Target questions allowed for exploring different aspects of local awareness related to the lionfish invasion (Fig. 3). In most cases, fishermen were aware that the lionfish was in Lebanon, and this awareness was primarily developed in 2016, a few months before the survey. The most relevant means of detecting species was personal observation (70.0% of the cases), realised either directly at sea or indirectly by fishermen showing their captures to others. Media tools such as television, newspapers and the internet were less effective (30%) in informing sea users about the presence of the lionfish in Lebanon, but were effective in conveying some key information, such as its poisonous spines and Red Sea origin. Most of the fishermen had accurate knowledge regarding basic aspects of this invasion; 92.1% knew this species can be safely consumed, 93.7% were aware of its poisonous spines and 76.6% knew the species was native to the Red Sea and may have entered the Mediterranean from the Suez Canal. Significantly, only 38.7% of respondents were informed that the lionfish is a potential hazard for native ecosystems, whereas others believed that this species is neutral or even good for the environment. Finally, when we asked for suggestions regarding management options (Fig. 4), 89.3% of the respondents spontaneously proposed to 'fish it intensively'. Most fishermen (65.3%) expressed no interest in collaborating on an eventual action of lionfish removal, whereas the others were more responsive.

## Discussion

Here, we used simple data, quickly acquired at low cost from local sea users through interviews, to assess recent changes occurring along the eastern Mediterranean coast. This practice has been used on other occasions to document alterations in the marine environment (Tesfamichael *et al.* 2014) and is particularly useful in studying invasive species, because dramatic changes can occur quite rapidly. The stakeholders' ecological knowledge allowed us to quickly gather information on the incipient lionfish invasion in Lebanon. Profound transformations of both the lionfish population and its interaction with local communities are envisaged for the future. Thus, the present findings represent a public-interest knowledge base and also serve as basic information against which future changes can be

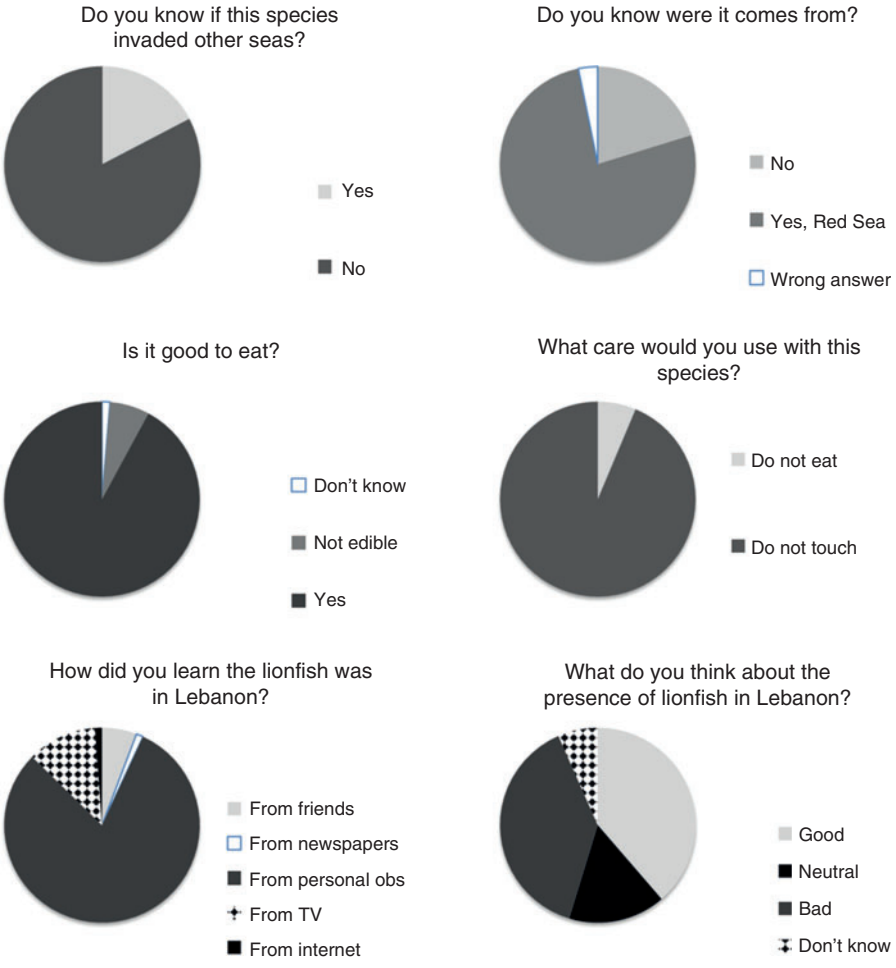


**Fig. 3.** Questions regarding awareness or risk perception and percentage distribution of related answers for 73 respondents. Only those people who had direct interactions with the lionfish were considered.

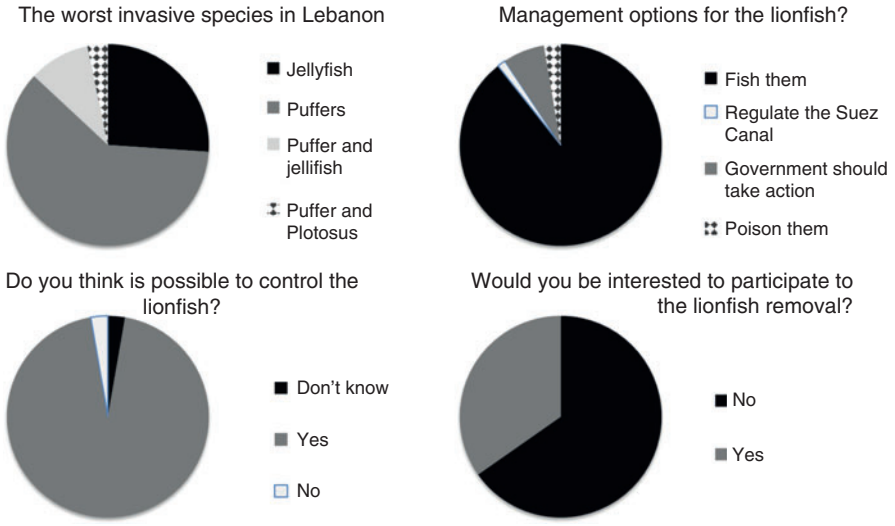


**Fig. 4.** Questions regarding management and related answers for 73 respondents.

evaluated. Significantly, every single capture or observation of the lionfish remained vivid in the memory of the fishermen and was recalled as an exceptional experience. Unlike events that are routine, and, therefore, difficult to remember, the encounters with the lionfish were recalled straightforwardly, as may happen with other unique events in self-narrative (Bradburn *et al.* 1987; Fitzgerald 1988). Once they began to describe and express their wonder for these unusual captures, they added many other details such as the time of day they departed, the state of the sea, the month and other particularities of that day. These recollections indicated that the first capture or observation of a conspicuous fish such as the lionfish had high personal significance. Furthermore, if we consider that the lionfish has a fairly distinctive and unique morphology, the probability of misidentification for this species is likely to be very low. These societal properties of the lionfish provide a considerable advantage in using a participative approach to studying and monitoring this particular invasion. Public participation is being widely used along the western Atlantic to remove this species from the environment (Malpica-Cruz *et al.* 2016) and to monitor its distribution (e.g. Biggs and Olden 2011). Hence, national governments and public institutions should incentivise similar initiatives along the coasts of the eastern Mediterranean, raising the awareness of stakeholders, and promoting their engagement in lionfish removal.

Awareness is critically important for environmental issues of public interest, and the internet and social media can be effective means of informing Lebanese fishermen about the potential risks associated with the invasive lionfish. Most fishermen also have cable TV, where they watch documentaries. Surprisingly enough, most of the fishermen (65.3%) expressed no interest in collaborating on the eventual removal of the lionfish. Local communities are currently suffering from complex socio-economical problems, and this is particularly the case for the fishermen, who belong to the poorest class in Lebanon. The willingness of stakeholders to be engaged in issues of environmental concern is, indeed, deeply influenced by their values, socioeconomic status and other cultural aspects (Schultz 2011). Moreover, coastal degradation, overfishing and invasive species have resulted in a severe alteration of Lebanese fishery resources (Carpentieri *et al.* 2009). This situation has pushed fishermen to struggle for basic material items needed for survival, such as food, electricity and water. Consequently, they have little time, interest and availability for helping and caring for a better environment. These complex socio-environmental problems would certainly limit the volunteer involvement of Lebanese fishermen, a factor that needs to be considered in responding to a true lionfish invasion in the eastern Mediterranean. Moreover, although the value of participatory research has been widely recognised by national governments, international bodies and funding agencies, most of the efforts thus far have focused on terrestrial environments, with only limited attention given to marine systems (Hyder *et al.* 2015). Considering that management initiatives for this species are not yet in force in the Mediterranean Sea, cultivating public knowledge and awareness can be critically important to supporting management initiatives in the near future. Researchers working on biological control have long recognised the significance of the relationship between scientists and the public as well as the importance of modern marine policy (Hyder *et al.* 2015). We hope our assessment of public knowledge and perceptions will serve to stimulate action towards the incipient lionfish invasion in the Mediterranean Sea.

## Acknowledgements

This work was developed without the support of external funding. We warmly thank all the Lebanese fishermen and other stakeholders for sharing their information with us and Ms K. Zahorchak for English editing.

## References

Anadón, J. D., Giménez, A., Ballestar, R., and Pérez, I. (2009). Evaluation of local ecological knowledge as a method for collecting extensive data on animal abundance. *Conservation Biology* **23**, 617–625. doi:10.1111/J.1523-1739.2008.01145.X

Azzurro, E., Moschella, P., and Maynou, F. (2011). Tracking signals of change in Mediterranean fish diversity based on local ecological

knowledge. *PLoS One* **6**, e24885. doi:10.1371/JOURNAL.PONE.0024885

Bariche, M., Torres, M., and Azzurro, E. (2013). The presence of the invasive lionfish *Pterois miles* in the Mediterranean Sea. *Mediterranean Marine Science* **14**, 292–294. doi:10.12681/MMS.428

Bariche, M., Torres, M., Smith, C., Sayar, N., Azzurro, E., Baker, R., and Bernardi, G. (2015). Red Sea fishes in the Mediterranean Sea: a preliminary investigation of a biological invasion using DNA barcoding. *Journal of Biogeography* **42**, 2363–2373. doi:10.1111/JBI.12595

Biggs, C. R., and Olden, J. D. (2011). Multi-scale habitat occupancy of invasive lionfish (*Pterois volitans*) in coral reef environments of Roatan, Honduras. *Aquatic Invasions* **6**, 347–353. doi:10.3391/AI.2011.6.3.11

Boughedir, W., Rifi, M., Shakman, E., Maynou, F., Ghanem, R., Souissi, J. B., and Azzurro, E. (2015). Tracking the invasion of *Hemiramphus far* and *Saurida undosquamis* along the southern Mediterranean coasts: a local ecological knowledge study. *Mediterranean Marine Science* **16**, 628–635. doi:10.12681/MMS.1179

Bradburn, N. M., Rips, L. J., and Shevell, S. K. (1987). Answering autobiographical questions: the impact of memory and inference on surveys. *Science* **236**, 157–161. doi:10.1126/SCIENCE.3563494

Carpentieri, P., Lelli, S., Colloca, F., Mohanna, C., Bartolino, V., Moubayed, S., and Ardizzone, G. D. (2009). Incidence of lessepsian migrants on landings of the artisanal fishery of south Lebanon. *Marine Biodiversity Records* **2**, e71. doi:10.1017/S1755267209000645

Crocetta, F., Agius, D., Balistreri, P., Bariche, M., Bayhan, Y., Çakir, M., Ciriaco, S., Corsini-Foka, M., Deidun, A., Zrelli, R., Ergüden, D., Evans, J., Ghelia, M., Giavasi, M., Kleitou, P., Kondylatos, G., Lipej, L., Mifsud, C., Özvarol, Y., Pagano, A., Portelli, P., Poursanidis, D., Rabaoui, L., Schembri, P., Taşkin, E., Tiralongo, F., and Zenetos, A. (2015). New Mediterranean biodiversity records (October 2015). *Mediterranean Marine Science* **16**(3), 682–702. doi:10.12681/MMS.1477

Dailianis, T., Akyol, O., Babali, N., Bariche, M., Crocetta, F., Gerovasileiou, V., Ghanem, R., Gokoglu, M., Hasiotis, T., Izquierdo-Munoz, A., Julian, D., Katsanevakis, S., Lipej, L., Mancini, E., Mytilineou, C., Ounifi Ben Amor, K., Ozgul, A., Ragkousis, M., Rubio-Portillo, E., Servello, G., Sini, M., Stamouli, C., Sterioti, A., Teker, S., Tiralongo, F., and Trkov, D. (2016). New Mediterranean biodiversity records (July 2016). *Mediterranean Marine Science* **17**, 608–626. doi:10.12681/MMS.1734

Elbarassi, H., Bashir, A. E., and Azzurro, E. (2014). *Fistularia commersonii* Rüppell, 1838 in the Mediterranean Sea: filling the Libyan gap. *Journal of Applied Ichthyology* **30**, 1047–1049. doi:10.1111/JAI.12470

Fitzgerald, J. M. (1988). Vivid memories and the reminiscence phenomenon: the role of a self narrative. *Human Development* **31**, 261–273. doi:10.1159/000275814

Hyder, K., Townhill, B., Anderson, L. G., Delany, J., and Pinnegar, J. K. (2015). Can citizen science contribute to the evidence-base that underpins marine policy? *Marine Policy* **59**, 112–120. doi:10.1016/J.MARPOL.2015.04.022

Kletou, D., Hall-Spencer, J. M., and Kleitou, P. (2016). A lionfish (*Pterois miles*) invasion has begun in the Mediterranean Sea. *Marine Biodiversity Records* **9**, 46. doi:10.1186/S41200-016-0065-Y

Kulbicki, M., Beets, J., Chabanet, P., Cure, K., Darling, E., Floeter, S. R., Galzin, R., Green, A., Harmelin-Vivien, M., Hixon, M., Letourneur, Y., Lison de Loma, T., McClanahan, T., McIlwain, J., MouTham, G., Myers, R., O'Leary, J. K., Planes, S., Vigliola, L., and Wantiez, L. (2012). Distributions of Indo-Pacific lionfishes *Pterois* spp. in their native ranges: implications for the Atlantic invasion. *Marine Ecology Progress Series* **446**, 189–205. doi:10.3354/MEPS09442

Malpica-Cruz, L., Chaves, L. C., and Côté, I. M. (2016). Managing marine invasive species through public participation: lionfish derbies as a case study. *Marine Policy* **74**, 158–164. doi:10.1016/J.MARPOL.2016.09.027

Sagarin, R., and Pauchard, A. (2010). Observational approaches in ecology open new ground in a changing world. *Frontiers in Ecology and the Environment* **8**, 379–386. doi:10.1890/090001

Schofield, P. J. (2009). Geographic extent and chronology of the invasion of non-native lionfish (*Pterois volitans* [Linnaeus 1758] and *P. miles* [Bennett 1828]) in the western North Atlantic and Caribbean Sea. *Aquatic Invasions* **4**, 473–479. doi:10.3391/AI.2009.4.3.5

Schofield, P. J. (2010). Update on geographic spread of invasive lionfishes (*Pterois volitans* [Linnaeus, 1758] and *P. miles* [Bennett, 1828]) in the western North Atlantic Ocean, Caribbean Sea and Gulf of Mexico. *Aquatic Invasions* **5**, S117–S122. doi:10.3391/AI.2010.5.S1.024

Schultz, P. (2011). Conservation means behavior. *Conservation Biology* **25**, 1080–1083. doi:10.1111/J.1523-1739.2011.01766.X

Schüttler, E., Rozzi, R., and Jax, K. (2011). Towards a societal discourse on invasive species management: a case study of public perceptions of mink and beavers in Cape Horn. *Journal for Nature Conservation* **19**, 175–184. doi:10.1016/J.JNC.2010.12.001

Scyphers, S. B., Powers, S. P., Akins, J. L., Drymon, J. M., Martin, C. W., Schobernd, Z. H., Schofield, P. J., Shipp, R. L., and Switzer, T. S. (2015). The role of citizens in detecting and responding to a rapid marine invasion. *Conservation Letters* **8**, 242–250. doi:10.1111/CONL.12127

Tesfamichael, D., Pitcher, T. J., and Pauly, D. (2014). Assessing changes in fisheries using fishers' knowledge to generate long time series of catch rates: a case study from the Red Sea. *Ecology and Society* **19**, art18. doi:10.5751/ES-06151-190118

Turan, C., Erguden, D., Gurlek, M., Yaghoglu, D., Uyan, D., and Uygur, N. (2014). First record of the Indo-Pacific lionfish *Pterois miles* (Bennett, 1828) (Osteichthyes: Scorpaenidae) for the Turkish marine waters. *Journal of the Black Sea – Mediterranean Environment* **20**, 158–163.