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Management of Threatened *Aphanius Fasciatus* at Il-Maghluq, Malta

Marion Zammit-Mangion[(1)], Alan Deidun[(2)], Robert Vassallo-Agius[(3)] and Melvin Magri[(3,4)]

[(1)] Dept of Physiology and Biochemistry, University of Malta
E-mail: mzam1@um.edu.mt
[(2)] IOI-MOC,University of Malta
E-mail: alan.deidun@um.edu.mt
[(3)] Malta Acquaculture Research Centre, Malta
E-mail: robert.j.vassallo@gov.mt
[(4)] E-mail: melvin.magri@gov.mt

Abstract

Over the last decade the distribution of *Aphanius fasciatus* Nardo has regressed sharply across the Maltese Islands despite numerous legal conservation instruments. In this study we present the results of a one-year phenological study at the protected wetland site known as Il-Maghluq. The *A. fasciatus* population structure and a number of water physical characteristics were monitored. The biotic data collected was found to be consistent with that of a highly vulnerable population. The authors make a number of management recommendations to improve the conservation status of this population.

Introduction

The euryhaline cyprinodontid *Aphanius fasciatus* Nardo, 1827 is one of three *Aphanius* species currently found in the Mediterranean Sea and is currently distributed in the saline coastal waters of the central and eastern Mediterranean, in salt flats and also occasionally in inland fresh water (Wildekamp, 1993). The species is a sexually dimorphic fish with a remarkable physiological capacity to tolerate abiotic constraints such as hypoxia, hyposalinity and hypersalinity associated with coastal marshland habitats.

Bianco (1995) describes the type habitat of the species as brackish-water coastal wetlands. The species' endemic status within the Mediterranean Basin, the disparate nature and regression of its *locus typicus* have raised concerns about the vulnerability of the species to local extinction. As a result, the conservation status of the species is described as 'unfavourable-inadequate' within most of the Mediterranean region, although some individual parameters are reported by Malta and Greece as 'favourable' (EEA, 2009). The fragmented nature of the distribution of the species is epitomized by the Maltese and Sicilian scenario. In the Maltese Islands, for instance, *A. fasciatus* is known only from a handful of sites (listed in Deidun et al., 2002) which are virtually isolated hydrologically from each other, whilst in Sicily, the species is concentrated mainly in the south-east of the island, with only scattered populations being found elsewhere (Lo Duca and Marrone, 2009).

A number of studies (e.g. Cimmaruta et al., 2003; Tigano et al., 2006) have confirmed the restricted degree of gene flow between different *A. fasciatus* populations by virtue of the fragmented nature of the species' distribution. As a result of such a sobering landscape, *Aphanius fasciatus* is considered to be threatened throughout its range, such that it is listed in Appendices II (Strictly protected fauna species) and III (Protected fauna species) of the Bern Convention (Convention on the Conservation of European Wildlife and Natural Habitats), and in Annex II (Animal and plant species of community interest whose conservation requires the designation of special areas of conservation) of the Habitats Directive (Council Directive 92/43/EEC (1) of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora as amended by Council Directive 97/62/EC of 27 October 1997) of the European Union.

Despite these instruments, recent surveys have revealed that over the last decade the distribution of this once abundant species has regressed sharply across the Maltese Islands, so that today *A. fasciatus* is now properly described from just four geographically distinct sites within the archipelago (Ghadira, Simar, Salina and il-Maghluq – refer to Fig. 1). Detailed phenological studies have only been conducted on two of the four Maltese populations of *A. fasciatus* – those at Ghadira and at Simar (Cilia, 1986; Zammit-Mangion, 2009; Zammit-Mangion et al., 2010; Zammit-Mangion and Deidun, 2010).

The current study aims to collect inter-seasonal phenological data for the *A. fasciatus* population at il-Maghluq, a protected coastal saline wetland/marshland located along the south-east coastline of Malta (Fig. 1), as well as inter-seasonal abiotic data for the same site, pursuant to formulating a set of management recommendations to spearhead the long-term viability of the species at the same site. By doing so, this study represents the first ever attempt at collecting such data for the il-Maghluq site.

Materials and Methods

Il-Maghuq marshland is also popularly known as the Marsascala fishponds since it consists of two interconnected fishponds lined by layered stones and remnants of a saline marshland. The site is a candidate Natura 2000 site for the Maltese Islands, being designated as a Special Area of Conservation (SAC) of International Importance in 2003 and best fits the description of IUCN Protected Areas Category IV since its

objective is to protect particular species or habitats. Anderson and Schembri (1989) list il-Maghluq as one of the five extant saline marshlands in the Maltese Islands, whilst the first State of the Environment Report for the Maltese Islands (Axiak et al., 2002) describes il-Maghluq as an existing but heavily engineered marshland. In testimony to to the heavily-disturbed nature of the reserve is the profuse presence of alien floral species, including *Aster squamatus* (narrow-leaved aster) and *Lavatera arborea* (tree mallow). Strident calls have been made for tangible, technically-advised conservation measures to be implemented at il-Maghluq marshland since the 1980's, mostly by the ENGO SSCN (nowadays known as Nature Trust Malta).

The wetland is approximately 230m at its longest point and 20m at its narrowest, covering an area of just 0.044km^2. The water complement of the main fish pond is maintained through 3 sources: (i) freshwater seepage from surrounding fields; (ii) precipitation and (iii) seawater influx below the coastal road separating the marshland from the sea. Since the connection between the marshland and the sea was severed upon construction of the coastal road, two 9-inch diameter underground pipes were placed under the coastal road to maintain such a maritime connection. Such a provision proved inadequate, however, and, following a major eutrophication event in June 1991 when several dead fish were observed at the surface of the fishponds, seawater had to be pumped from the bay into the fishponds to mitigate against the drop in dissolved oxygen.

Fig. 1 gives the geographical position of il-Maghluq wetland within the Maltese Islands, as well as the location of three other Maltese coastal sites still currently harbouring populations of *A. fasciatus*. Fig. 2 illustrates the perimeter of the il-Maghluq wetland, as well as indicating the biotic and abiotic sampling sites within the same wetland.

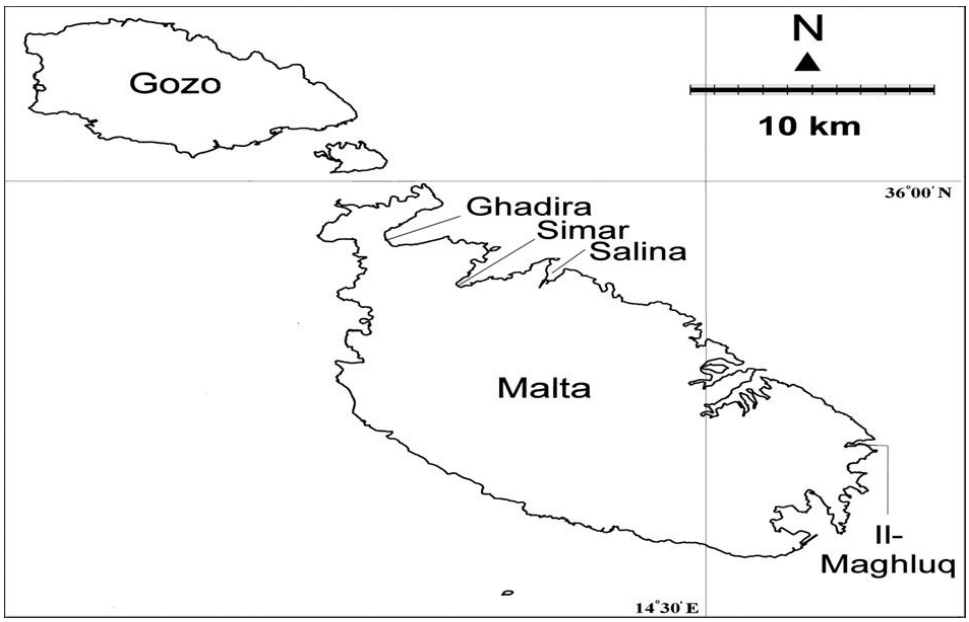

Fig. 1: Geographical location of the Maltese coastal sites still harbouring *A. fasciatus* populations.

Sampling was carried out monthly over one year between September 2010 and August 2011. Baited minnow traps (40cm in diameter and 8mm mesh size) were deployed, approximately 1.5m from the shoreline in the innermost end of the bay (Fig. 2). The traps were monitored frequently to ensure that the killifish did not become stressed. After 20 minutes the traps were collected, opened and the fish lengths and gender were recorded *in situ*, with the fish being released back into the wild thereafter. For each monthly visit, this procedure was repeated three times.

During the same period, a number of abiotic parameters (temperature, pH, salinity, dissolved oxygen, conductivity, TDS, phosphate and nitrite concentration) were monitored at three different locations (zones 1-3) along the length of il-Maghluq wetland (Fig. 2). The biotic sampling site (Fig. 2) was in close propinquity to abiotic sampling zones 2 and 3.

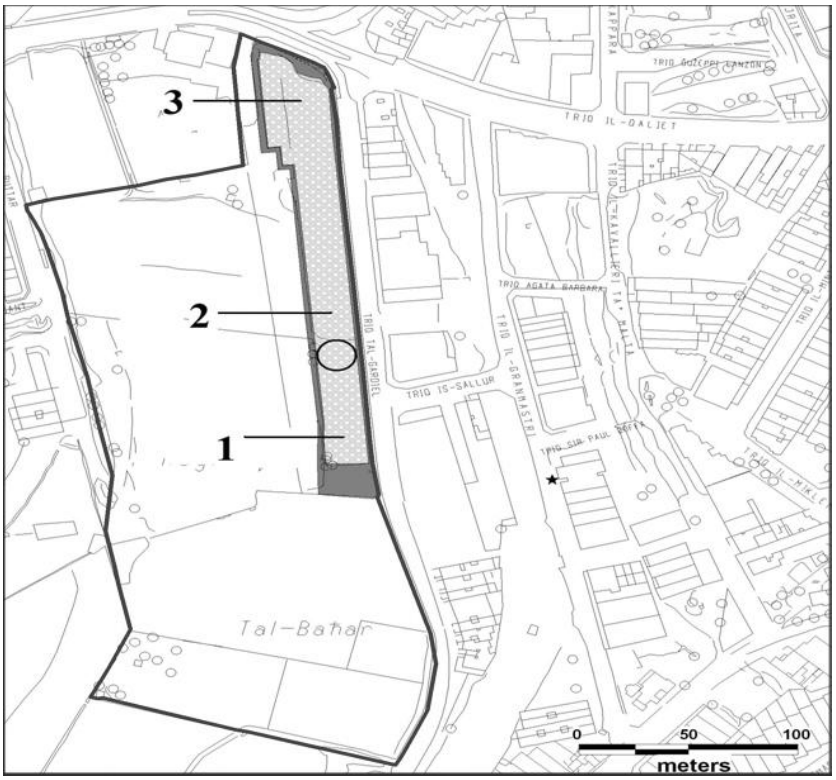

Fig. 2: Perimeter of the il-Maghluq wetland with indications of the biotic (denoted by an oval) and abiotic (zones 1-3) sampling zones. Map adapted from www.mepa.org.mt.

Results

A total of 417 fish were sampled confirming that the population is relatively small in size. The population was skewed in favour of the adults with a total of 294 females and 105 males recorded. The juvenile stage (less than 28mm in size) was found to be poorly represented with just 18 individuals recorded during the sampling period. The population distribution was further explored by plotting the abundance of males, females and juveniles *A. fasciatus* (Fig. 3).

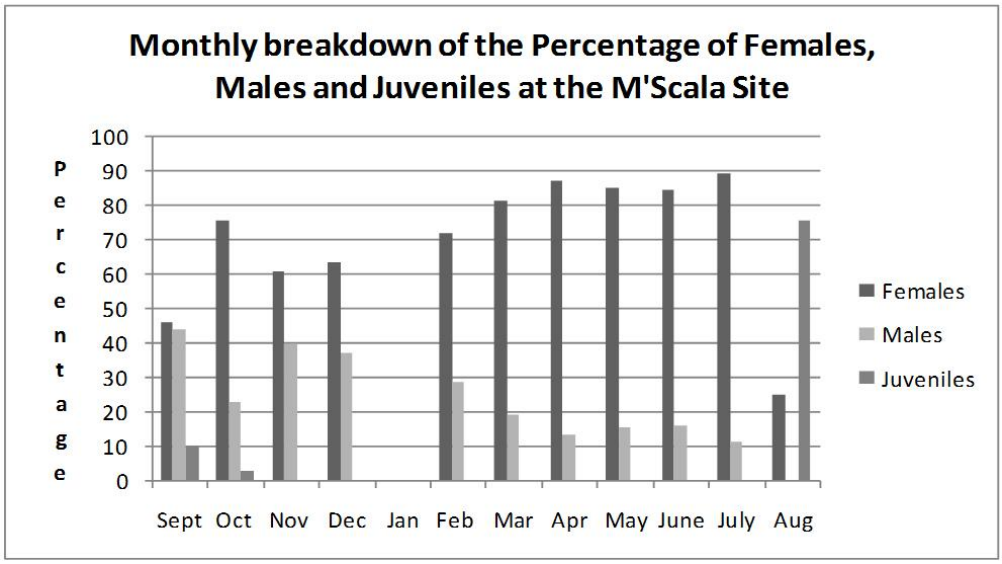

Fig. 3: Monthly variation in adult males, females and juveniles.

Within this population, females were found to be most abundant and for most of the year they constituted well over 60% of the population. A decrease in the number of females was recorded during August and September and this may be related to the increased cost of maintaining reproductive effort under harsh abiotic conditions associated with the Maltese summer months. Fig. 3 also shows that the number of males in the Maghluq population was consistently low and for most of the year they constituted less than 25% of the female numbers. In particular there was a significant decrease in the number of males during the summer months when the habitat was subject to high temperatures and rapid evaporation. This drop has been noted at other sites and offers support for the proposal that as the depth of the water decreases, there is less opportunity for the brightly coloured males to escape predators (Zammit-Mangion, 2009).

Despite the geographical isolation of this site, the breeding cycle of the killifish at Il-Maghluq appears to mirror that recorded at the Ghadira wetland with the number of juveniles also peaking in August (Zammit-Mangion, 2009). However at the Maghluq site juvenile reproduction and recruitment do not appear to be taking place successfully with just 4.3% of the overall population comprising the juvenile stage. Even then, mortality was high with juveniles showing sharp declines in number by the end of the summer (down from 78% of the population in August to just over 40% by September). Table 1 summarises the inter-seasonal variation in the values of the abiotic parameters monitored at the site.

Large inter-seasonal fluctuations were recorded for different physical parameters. In particular, water temperatures recorded during the months of July (29.9-31.2^{0}C) and August (30.3-32.1^{0}C) were more than double those recorded during the month of February (13.9-14.5^{0}C). Dissolved oxygen (DO) levels during the months of June-August were less than half those recorded during the previous month (May 2011) and during January 2011. In general, DO and levels were lower in zones 2 and 3 of the Maghluq wetland in view of their lower propinquity to the sea.

Table 1: Inter-seasonal variation in abiotic parameters monitored at three different zones (Fig. 2) within il-Maghluq Natura 2000 site.

DATE	Zone within reserve	PARAMETER							
		Temp ^{0}C	pH	DO (% Sat)	Salinity (g/L)	Conduc. (Ms/cm)	TDS (g/L)	Phosphate (mg/L)	Nitrite (g/L)
Oct 2010	1	17.2	8.69	103	18	28.8	19.3	0.08	0.003
	2	16.6	8.75	108	17	28.3	18.8	0.02	0.003
	3	16.5	8.68	109	16	27.7	18.5	0.04	0.001
Nov 2010	1	21.0	8.22	138	34	53.3	35.5	0.02	0.060
	2	20.8	8.20	109	36	54.4	36.4	0.02	0.021
	3	20.2	8.22	119	37	55.2	37.0	0.02	0.023
Dec 2010	1	13.1	7.78	94	18	29.7	19.9	0.03	0.147
	2	14.5	8.07	106	24	39.9	26.8	0.32	0.060
	3	15.7	8.10	97	28	44.8	29.9	0.02	0.021
Jan 2011	1	18.4	8.02	201	32	48.2	32.2	<0.02	0.060
	2	16.2	7.71	107	34	51.4	34.5	<0.02	0.016
	3	16.7	7.76	108	35	51.7	34.7	<0.02	0.025
Feb 2011	1	14.5	8.06	108	24	37.6	25.1	<0.02	0.042
	2	14.1	7.75	83	25	39.0	25.9	<0.02	<0.001
	3	13.9	7.92	84	26	40.1	27.0	0.02	0.016
Mar 2011	1	22.3	8.27	138	26	39.6	26.4	<0.02	0.028
	2	19.2	8.39	118	30	46.1	30.9	<0.02	0.019
	3	18.2	8.46	119	31	47.9	32.0	<0.02	0.012
Apr 2011	1	26.1	8.52	164	28	45.6	30.5	0.10	0.093
	2	24.1	8.25	108	29	46.9	31.4	<0.02	0.077
	3	24.1	8.18	96	32	50.1	33.5	<0.02	0.046
May 2011	1	30.8	8.52	230	38	52.7	35.3	0.06	0.003
	2	28.1	8.33	185	39	52.8	35.3	<0.02	<0.001
	3	27.9	8.29	193	39	52.6	35.1	0.02	<0.001
Jun 2011	1	28.7	7.96	56	40	51.9	34.7	0.03	0.028
	2	28.0	8.08	87	39	56.4	37.7	0.03	0.001
	3	28.0	8.14	112	39	56.4	37.8	0.06	0.001
Jul 2011	1	31.2	7.98	37	37	48.4	32.4	0.07	>0.500
	2	30.4	8.15	100	38	50.6	33.9	0.02	0.079
	3	29.9	8.17	110	38	14.6	9.8	0.02	0.046
Aug 2011	1	32.1	8.02	76	36	56.2	37.5	0.04	0.036
	2	30.4	8.07	96	37	56.4	37.7	0.10	0.028
	3	30.3	8.06	89	37	56.3	37.7	<0.02	0.009

Similar extensive variability was also observed within salinity, TDS and conductivity values for water samples collected seasonally at il-Maghluq, with salinity values generally being higher during the dry summer period. The high phosphate and nitrite values are consistent with eutrophic conditions generally encountered within enclosed water bodies and may be explained in terms of the extensive use of pesticides in contiguous agricultural land.

Discussion

The results of the population study at Il-Maghluq are partly consistent with a life strategy that involves investment in a high reproductive effort and therefore favours a greater number of females (Leonardos and Sinis, 1999; Zammit-Mangion, 2009). Given the relatively high presence of females within the population, reproduction and

recruitment should proceed seamlessly. However, the data collected in this study suggests otherwise, with a number of features in fact reflecting a highly vulnerable population, such as the low percentage survival of juveniles, low presence of juveniles and the overall low population numbers (both adult female and male).

The authors postulate that the overall small size of the population is due to stress-induced mortality, arising from the large seasonal fluctuations in abiotic factors, the stressful abiotic environment, especially during the summer months and especially in terms of dissolved oxygen and water temperature. Such fluctuations are the consequence of a number of forcings, including natural ones (freshwater runoff at the mouth of the valley after heavy rainfall) and anthropic ones (e.g. engineering works at the wetland-sea interface, runoff of fertiliser- and pesticide-contaminated runoff from contiguous fields, extensive dumping of oil and other wastes into the wetland). The decrease in dissolved oxygen levels during summer months is compounded by occasional eutrophication events witnessed at the surface of the fishponds.

During the sampling period, significant changes in the water level at il-Maghluq were observed, with a sharp drop of ca. 1m in the water level observed during January 2011 and extending till July 2011 and presumably related to hydrodynamic alterations induced by complex changes to sea-wetland exchange volumes or due to coastal engineering works.

At the il-Maghluq fish ponds, *A. fasciatus* individuals were almost exclusively restricted to the innermost sections, most distanced from the sea, within a ca. $100m^2$ pond area. The authors postulate that the killifish species is mostly absent from the other seaward swathes of the fish ponds due to the profuse presence of *Mugil cephalus* (striped mullet) within the seaward areas, with such a fish species known to predate (non-selectively) on *A. fasciatus* individuals, and due to the presence of waterfowl (mostly wilfully introduced) within the same swathes of the fish ponds. Additionally, the innermost sections of the fish ponds may be providing the right ambient conditions for the reproduction and feeding of the cyprinodontid species, being densely populated by *Juncus maritimus* (sea rush – this species is only sparsely found within the rest of the reserve). The innermost fish pond swathe also supported dense phytoplankton assemblages, which were sampled only once for characterisation purposes in spring 2011, consisting mainly of *Ulva* (= *Enteromorpha*) *intestinalis, Oscillatoria margaritifera*, *Pleurosigma* sp., colonial *Coscinodiscus* sp., unidentified naviculoid diatoms and green flagellates similar to *Chlamydomonas* sp. (Edwin Lanfranco, personal communication).

The spatial concentration of the *A. fasciatus* population to a highly restricted and impacted area at il-Maghluq heightens its degree of vulnerability to extinction. The ephemeral nature of the il-Maghluq *A. fasciatus* population is indirectly acknowledged within some scientific (e.g. Deidun et al., 2002) and popular/grey (e.g. Debono, 2011) publications which do overlook the species at il-Maghluq and do not report it, hinting at the small size of the *A. fasciatus* population at il-Maghluq. The management

recommendations by the authors of this study to improve the conservation status of the *A. fasciatus* population at il-Maghluq marshland include the following:

(i) the conduction of EIA studies prior to affecting any engineering works which might alter hydrodynamics within the fish ponds;

(ii) the control of the waterfowl population within the reserve;

(iii) the gradual conversion to organic farming in contiguous agricultural land;

(iv) the long-term monitoring of the *A. fasciatus* population at il-Maghluq to anticipate mass mortality events in order to be in time to adopt mitigatory action;

(v) the deployment of a small-mesh barrier at the marshland-sea interface to preclude the influx of large fish individuals which could possibly predate on *A. fasciatus* – regular fish censuses should also be held to characterise the fish assemblages within the fish ponds themselves and

(vi) the adoption of surveillance facilities in order to legislate against dumping of oil and other water-borne wastes.

The restricted spatial scale of il-Maghluq reserve and its propinquity to highly-frequented areas (resulting in turn in extensive 'edge') render its management challenging. The *A. fasciatus* population at il-Maghluq, along with the population at Salina, represents the only founder killifish population within the Maltese Islands, since killifish populations at Ghadira and Simar were established through the translocation of individuals from Salina (Deidun et al., 2002), whilst another founder killifish population at Marsa is presumably extinct. For this reason, the conservation of the *A. fasciatus* population at il-Maghluq is paramount. For such conservation to materialise, previous knee-jerk management practices, including misguided afforestation schemes (which included the planting of non-indigenous tree species within the reserve) and impromptu coastal engineering works must be abandoned and be replaced by technically-guided and scientifically-rigorous management.

Conclusions

The results of the one-year study of the *A. fasciatus* population at the Il-Maghluq marshland site suggest a population which is highly vulnerable, characterised by a low numbers of juveniles (possibly due to a high juvenile mortality) and extremely low and widely fluctuating population numbers. Furthermore, the *A. fasciatus* population experienced significant seasonal abiotic fluctuations within the habitat, as well as anthropic interference in the form of unassessed engineering works, chemical run-off from neighbouring fields and illegal dumping of waste material. Within such a sobering scenario and if the population is not to become extinct, the authors recommend that management measures should be adopted urgently at the site, including the obviation of introduced predators of *A. fasciatus* from the site, including waterfowl and *Mugil cephalus*, the adoption of organic farming practices in contiguous farmland, the installation of surveillance facilities to legislate against dumping of waste oils and other pollutants in the reserve and the prior assessment of the hydrodynamic impact of any proposed coastal engineering works.

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