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I. GATÌ[1], M. D'ALESSANDRO[2], S. GIACOBBE[1], V. ESPOSITO[2]

[1]ChiBioFarAm Department, Messina University
[2]National Institute of Oceanography and Applied Geophysics-OGS
ivan.gati@studenti.unime.it

DPSIR (DRIVING FORCES-PRESSURES-STATE-IMPACT-RESPONSE) MODEL APPLIED TO TWO SICILIAN TRANSITIONAL AREAS TO A BETTER MANAGEMENT

MODELLO DPSIR (DRIVING FORCES-PRESSURES-STATE-IMPACT-RESPONSE) APPLICATO A DUE AREE DI TRANSIZIONE SICILIANE PER UNA MIGLIORE GESTIONE

Abstract - *DPSIR models were applied to the pressures and impacts identified for two transitional areas on the northeastern Sicilian coast: the Capo Peloro and Oliveri-Tindari lagoons, both belonging to Sites of Community Importance (SCIs) of the Natura 2000 network. The "driving forces" included: climate change, tourist flows, maintenance, and productive activities. The "pressure" indicators included extreme events (eg. eutrophication/anoxia), the presence of nonindigenous species and pollution. Benthic communities were considered as "state" indicators, while biodiversity loss and economic value were assigned to the "impact" category. The results showed that the two lagoons are subject to both shared drivers, mainly temperature fluctuations and low water exchange, and different driving forces that affect the characteristics of the ecosystems and depend essentially on the destination of the two areas: Peloro for shellfish farming and Marinello for tourism. Based on these observations, some guidelines for a better management of the areas have been formulated.*

Key-words*: DPSIR model, transitional area, Natura 2000 network, Visual Census, NE Sicily.*

Introduction - Transitional environments (TEs), as areas originate from the mixing of coastal seawater and continental freshwater, are characterized by high productivity and remarkable diversity of habitats and species, providing regulating, provisioning, and cultural ecosystem services. TEs are important nursery areas for commercial fish species and sites of traditional shellfish farming, whose counterpart is a high anthropogenic pressure often leading to biodiversity loss and depletion of ecological status and resources (Pérez-Ruzafa *et al*., 2019).
Given the extreme complexity of these environments, the use of models such as DPSIR can help to identify the key environmental issues and attempt to provide guidelines for better management (Newton *et al.,* 2014). DPSIR, which is used by many agencies such as the European Environment Agency (EEA) and programs such as the United Nations Environment Program (UNEP), allows to evaluate a variety of pressures, states, and scenarios (Zaldivar *et al*., 2008), describing the interactions between society and the environment.
In this study, the DPSIR model was applied to the pressures and impacts identified for two transitional areas on the northeastern Sicilian coast belonging to Natura 2000 Network: Capo Peloro (ITA 030008) and Oliveri-Tindari Lagoons (ITA 030012). The Capo Peloro lagoon, located on the northern coast of the Strait of Messina, close to the homonymous city, consists of two interconnected basins, Ganzirri and Faro, both of great ecological and economic importance. Faro Lake, with a maximum depth of 28 m, is a meromictic system with anoxic water below the 10 m depth (Leonardi *et al.,* 2009) and is characterized by a high biodiversity. Ganzirri Lake, due to high primary productivity, is suitable for the exploitation of biological resources, especially shellfish. Shellfish farming has been widespread in both lakes since ancient times, and currently there is a thriving market focused on *Mytilus galloprovincialis*, *Crassostea gigas*, and clams (*Cerastoderma glaucum, Polititapes aureus e Ruditapes decussatus*) (Di Bella *et*

al., 2010). The Oliveri-Tindari lagoon, a small brackish water system on the Tyrrhenian coast of Sicily, is characterized by marked geomorphological dynamics and high structural and hydrobiological complexity. The lagoon, which is one of the last examples of untouched brackish coastal areas in northeastern Sicily, consists of four pounds (Marinello, Mergolo della Tonnara, Verde, and Porto Vecchio), well differentiated in their biochemical and physical features (Giacobbe and Leonardi, 1986).

Materials and methods - To develop the DPSIR model, various indicators were examined for the two study areas. Among the "driving forces": climate changes, tourist flows, maintenance and productive activities. The "pressure" indicators include the frequency of extreme events (eutrophication/anoxia), the spread of NIS, pollution, and the annual biomass of farmed species (mollusks). Benthic community composition and structure were considered "status indicators", while biodiversity loss and economic value were assigned to the "impact indicators" category.
In order to best investigate the driving forces and pressures affecting the area, local ecological knowledge (LEK) was collected through interviews with stakeholders and citizens to obtain information on ecological processes, changes and local problems. At this scope, two questionnaires (one for each of the study area) were opportunely set up. Then, visual census activities were carried out by scientific operators in both systems to assess the structure and composition of the icthyofauna and the presence of non indigenous and indicator species. Benthic and pelagic fish species were separetely investigated. Four samplings for each lakes were carried out from March to June 2022. Due to the different sizes of the basins, two different methodologies have been applied. In the Tindari-Oliveri lagoon, three transects were conducted along the entire length of the four lakes (two at the edge and one in the middle), while in the Capo Peloro lagoon, one transect of 30 minutes was conducted for both lakes. Typology and abundance of the species were noted on PVC panels. Pictures and videos were also collected to allow the subsequent identification of the doubtful species.

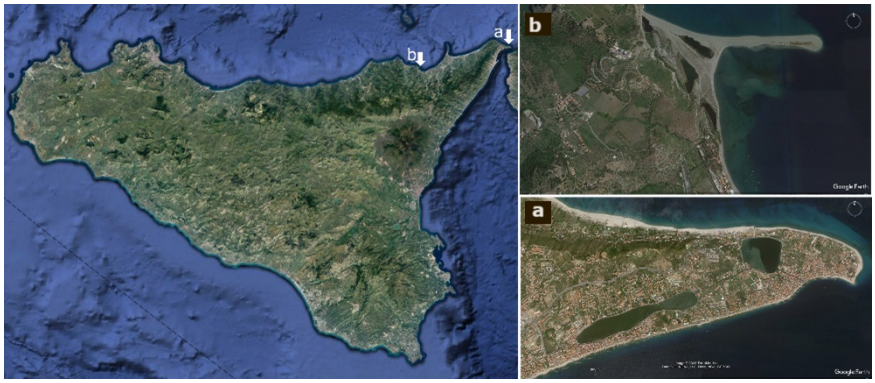

Fig 1 - Sites of study in the Sicily (left panel): Capo Peloro (a); Tindari – Oliveri (b)
Aree di studio in Sicilia (riquadro di sinistra): Capo Peloro (a); Tindari - Oliveri (b)

Results - The interviews allowed to identify pollution from anthropogenic activities and siltation of the seabed as the main points of criticism in both investigated areas. In addition, the intervieweds reported anoxic phenomena in both study areas. The visual census activities led to the identification of a total of 3404 specimens belonging to 9 species in the Oliveri-Tindari area (Tab.1). The most abundant species was *Atherina boyeri* (86% of total abundance). In Capo Peloro, a total of 4690 specimens belonging to 18 taxa were identified. The most abundant species were: *Atherina sp.* (34.9%), *Liza sp*. (29.8%) and Mugilidae (23.2%). Regarding to non-native species, the seaweed *Caulerpa racemosa* was detected in all lakes except in Mergolo della Tonnara, the bivalve *Pinctada radiata* and *Brachidontes pharaonis* only in Capo Peloro system. Among

the indicator species the threatened mussel *Pinna nobilis* was detected only in Faro Lake. In addition, the visual census led to the identification of several species of ecological importance such as *Aphanius fasciatus*, *A. anguilla*, *Cymodocea nodosa*, *E. marginatus* and *S. abaster*.

Tab. 1 - Results of visual census in Oliveri- Tindari and Capo Peloro lakes.
Risultati del visual census nei laghi di Oliveri- Tindari e Capo Peloro.

	Mergolo	Porto Vecchio	Marinello	Verde	Faro	Ganzirri
Anguilla anguilla (Linnaeus, 1758)	–	5	–	–	2	–
Aphanius fasciatus (Valenciennes, 1821)	–	–	–	–	9	–
Aphanius sp. Nardo,1827	–	–	–	404	1437	201
Atherina boyeri Risso,1810	–	1	–	–	–	–
Atherina sp. Linnaeus,1758	–	–	–	–	1	–
Blennidae ind. Rafinesque, 1810	–	–	–	–	–	–
Chelon auratus (Risso, 1810)	–	–	–	–	470	5
Chelon labrosus (Risso, 1827)	–	1	–	–	–	–
Chromis chromis (Linnaeus, 1758)	–	–	–	–	4	–
Diplodus lineatus (Valenciennes, 1830)	–	–	–	–	1	–
Diplodus sp. Rafinesque, 1810	–	–	–	–	1	–
Epinephelus marginatus (Lowe, 1834)	–	1	1	–	–	–
Gobius niger Linnaeus, 1758	72	396	2409	2669	–	–
Gobius sp Linnaeus, 1758	–	–	–	–	–	2
Liza sp. Jordan & Swain, 1884	–	–	–	–	270	1130
Millerigobius macrocephalus (Kolombatovic, 1891)	–	5	–	5	1	–
Mugil cephalus Linnaeus, 1758	–	–	1	1	44	–
Mugilidae ind. Jarocki, 1822	–	–	–	–	1010	81
Scorpaena sp. Linnaeus, 1758	–	–	–	–	3	–
Sygagnatus abaster Risso, 1827	1	2	–	1	1	–
Symphodus roissali (Risso, 1810)	–	–	–	–	1	–
Thalassoma pavo (Linnaeus, 1758)	–	–	–	–	15	–
Torpedo torpedo (Linnaeus, 1758)	–	–	–	–	1	–

Conclusions - The application of DPSIR model to all the data collected provided an insight of the driving forces and, consequently, the pressures acting on the two Natura 2000 sites as well as resulting impacts, allowing to identify some management actions that could improve the actual status of both areas. LEK activities reveal that the main criticisms that afflict the areas are linked to climate change and anthropogenic pollution. The shallow depths and high temperature together with the inefficient water exchange and recirculation in both systems, generates anoxic phenomena, causing periodic instability of the lagoon ecosystems. This phenomenon in the Ganzirri Lake is accentuated by the very high biomasses reaches by the invasive bryozoan *A. verticillum* and the algae *Chaetomorpha linum*, that obligate the fishermen to remove it manually to avoid massive molluscs mortality. The litter criticality, instead, seems to be related to the different typology of anthropogenic pressures that afflict the areas: shell farm for Peloro and tourism for Oliveri-Tindari.
Regarding the status of the areas, even if the fish communities resulted mostly composed by gregarious and tolerant species such as *Atherina boyeri* and Mugilidae, typical of these environments, the settlement of some protected and ecologically important species has been recorded. Extraordinary is the record of a typical pelagic species as *E. marginatus* (Annex III of the Berne Convention and Red List IUNC). The record of *S. abaster* and of *A. anguilla* in both systems underlines the importance of these environments as refuges for threatened species, as also confirmed by the occurrence of the indicator bivalve *Pinna nobilis* in Faro Lake. In fact, in recent years this species has been subjected to disease by the protozoa *Haplosporidium pinnae*, which have decimated natural populations (Donato *et al.*, 2021). However, the two

lagoon systems are known to be also affected by the invasion of numerous non-indigenous species mainly invertebrates introduced by aquaculture and maritime traffic vectors and capable of significantly altering the structure of the ecosystem and affecting all its components (Giacobbe, 2012). Considering this, one of the suggested management measures will be to provide programs to monitor the entry and spread of these species and, where possible, try to eradicate them. On the other hand, greater protection of important habitats could be envisaged. Together with these measures mostly related to the natural dynamics of the ecosystem, a greater attention in waste management by increasing the number of waste collection bins and through awareness-raising actions towards users and citizens and an alternative use of harmful biomass through industrial transformation will be advisable.
In conclusion, although the data collected and the DPSIR model applied evidence that the ecological status of the two transitional areas is quite good and maintenance and protection measures are already provided, more focused and careful management would be desirable.

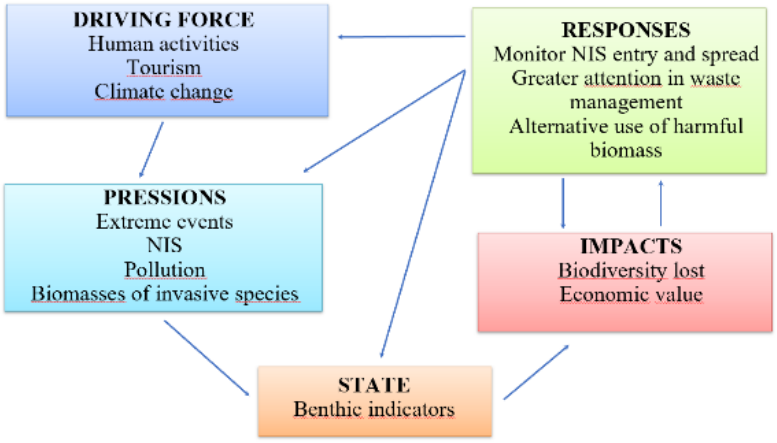

Fig. 2 - DPSIR model
Modello DPSIR

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