

Supplementary information

An integrated Pan-European perspective on coastal Lagoons management through a mosaic-DPSIR approach

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DPSIR framework application to each case study

Introductory note

The DPSIR framework describes the interactions between society and the environment, allowing to structure and communicate policy-relevant research: D - drivers, P - pressures, S - state change, I - impact, R – responses ¹. A mosaic-DPSIR is an

adapted framework, where DPSIR cycles from several drivers in an environmental system are combined, may have interactions among each other, and, as such, need integrated management recommendations (responses) ¹.

In this study, we applied the mosaic-DPSIR for each case study lagoon. Initially, DPSIR cycles of the anthropogenic drivers considered as most important for each lagoon were done (Table 1 from the paper), by combining information from different sources: from the deliverables and technical briefs from LAGOONS project on the current knowledge base and knowledge gaps, problem based sciences analysis and references therein (WP2, WP3, WP7), focus groups and citizen jury briefs (WP4) with information from the lagoons' end users (stakeholders, policy makers, general public) (see e.g. in ²) and on the expert judgement from the LAGOONS different team members. All documentation is available in ³ and in the LAGOONS website, <http://lagoons.biologiaatua.net>. However, some briefs are only available in the native language (e.g. focus group and citizen jury briefs).

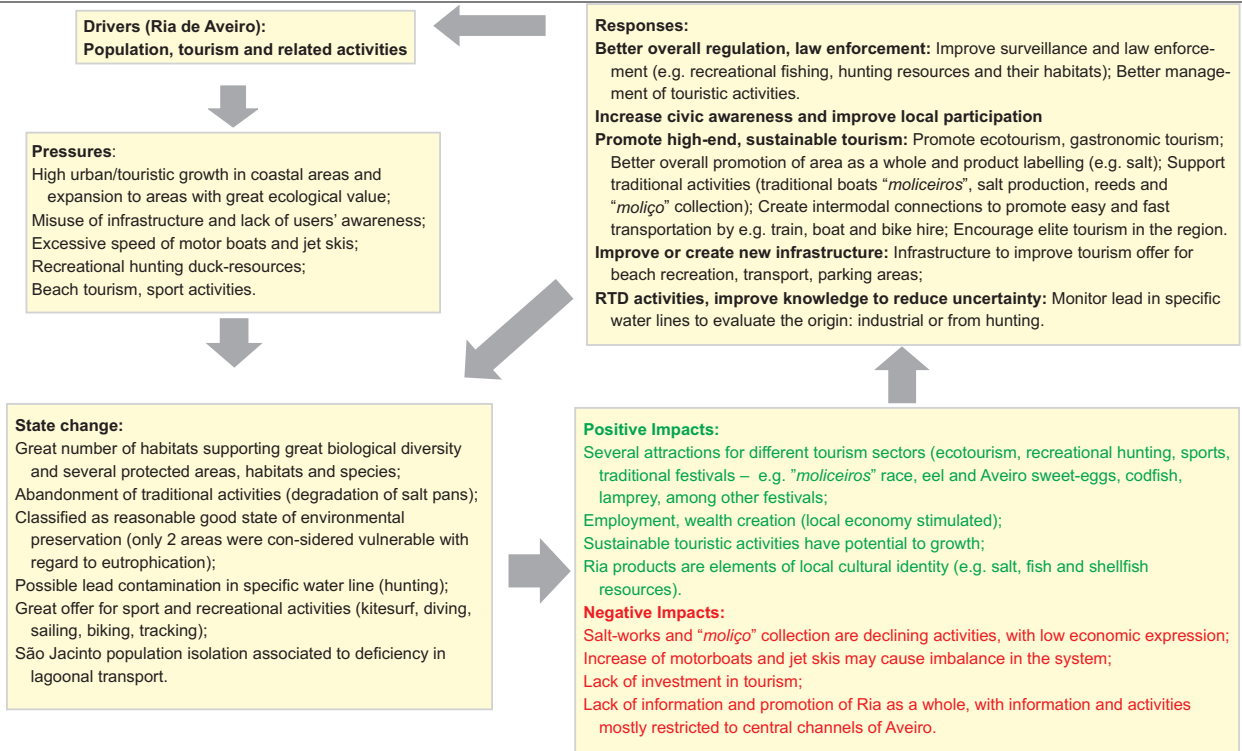
Next, all DPSIR cycles and mosaic-DPSIR are presented for each lagoon: Ria de Aveiro, Mar Menor Lagoon, Tyligulskyi Liman Lagoon, and Vistula Lagoon. In the *Responses*, common general responses among cycles are marked in bold.

Common references

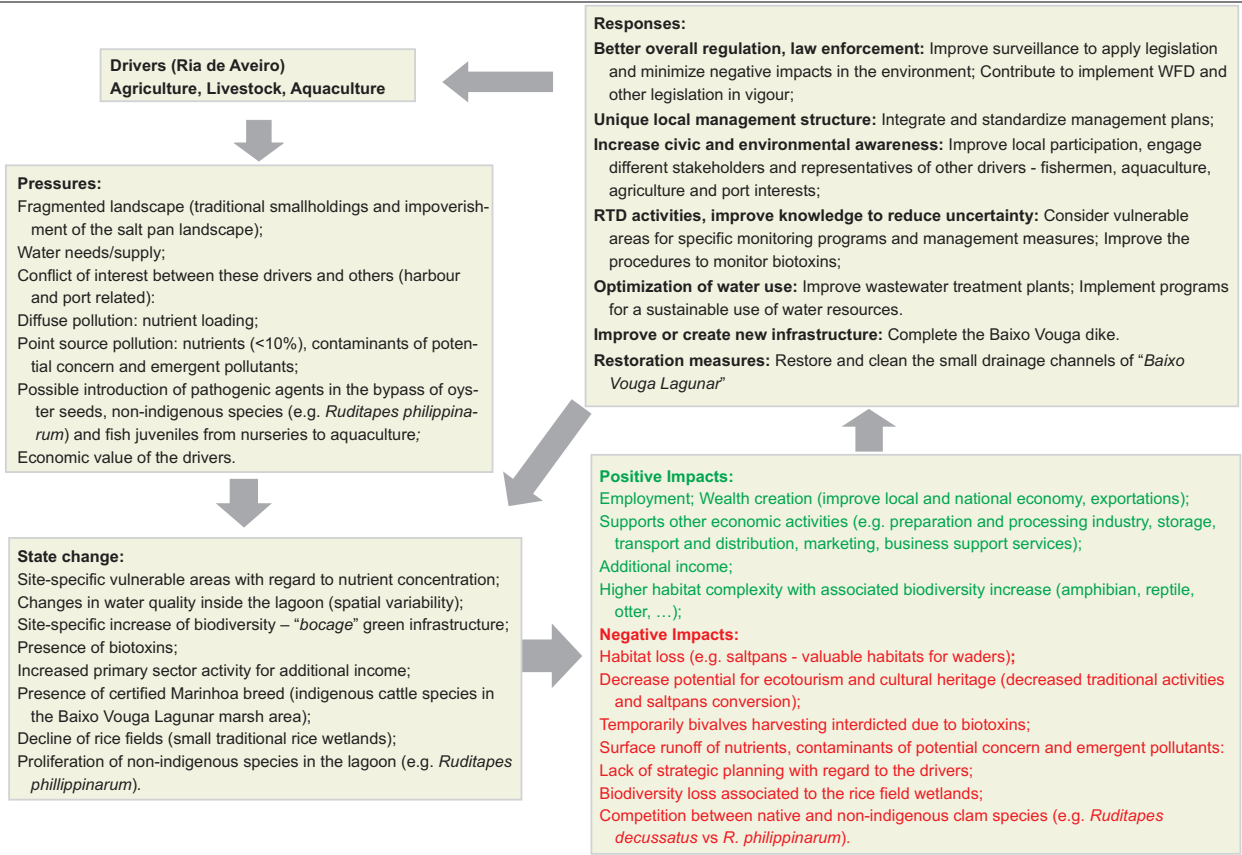
1. Atkins, J. P., Burdon, D., Elliott, M. & Gregory, A. J. Management of the marine environment: Integrating ecosystem services and societal benefits with the DPSIR framework in a systems approach. *Mar Poll Bull* **62**, 215–226 (2011).
2. Sousa, L. P., Lillebø, A. I., Gooch, G. D., Soares, J. A. & Alves, F. L. Incorporation of Local Knowledge in the Identification of Ria de Aveiro Lagoon Ecosystem Services (Portugal). *J Coast Res* **65**, 1051–1056 (2013).
3. Lillebø, A. I., Stålnacke, P. & Gooch, G. D. *Coastal Lagoons in Europe: Integrated Water Resource Strategies*. (IWA Publishing) (2015, forthcoming).

Ria de Aveiro

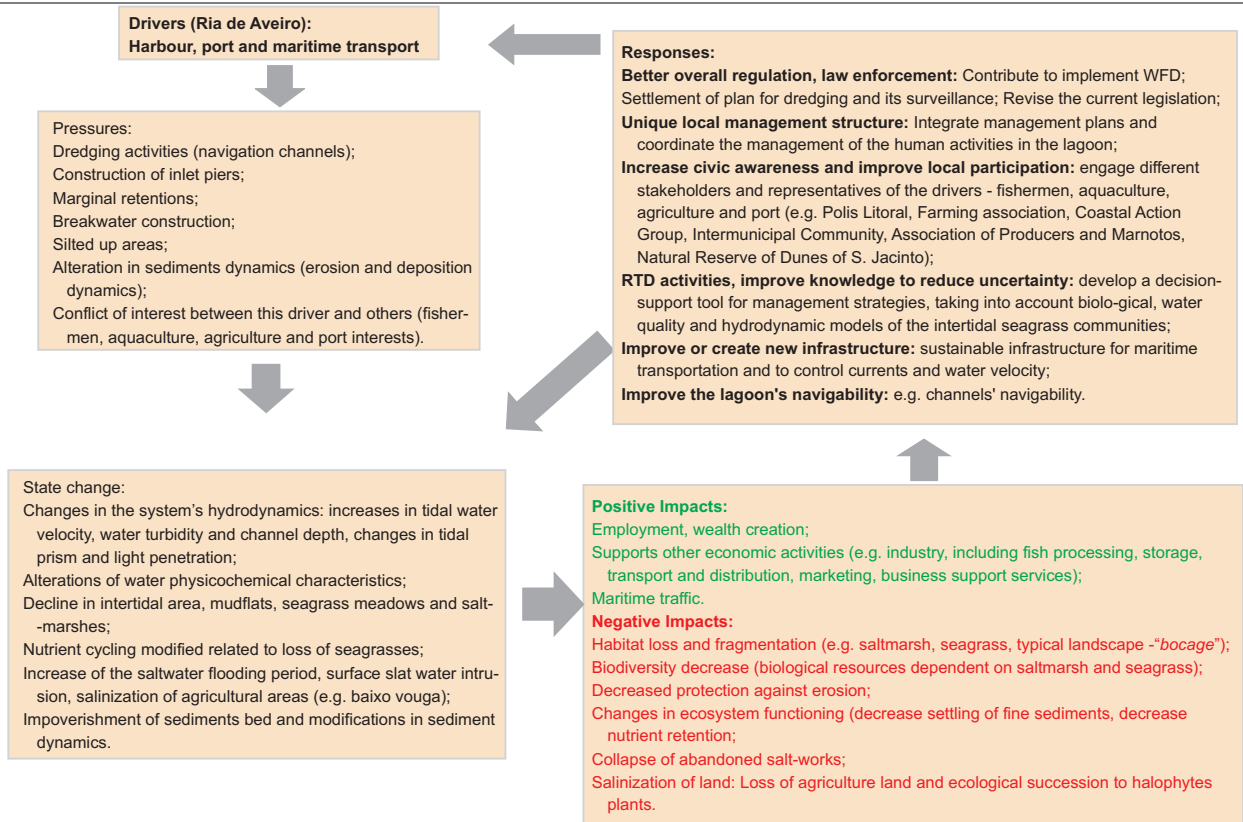
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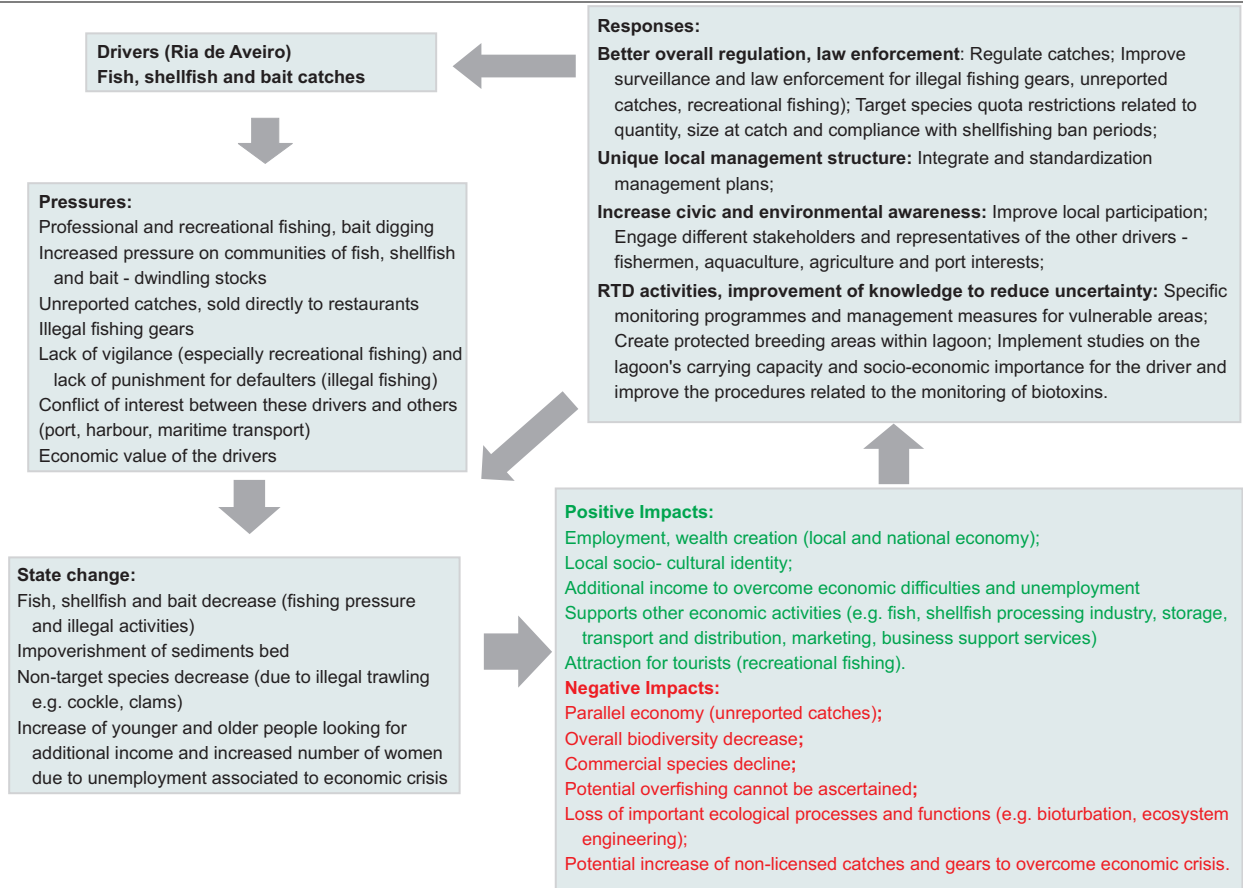
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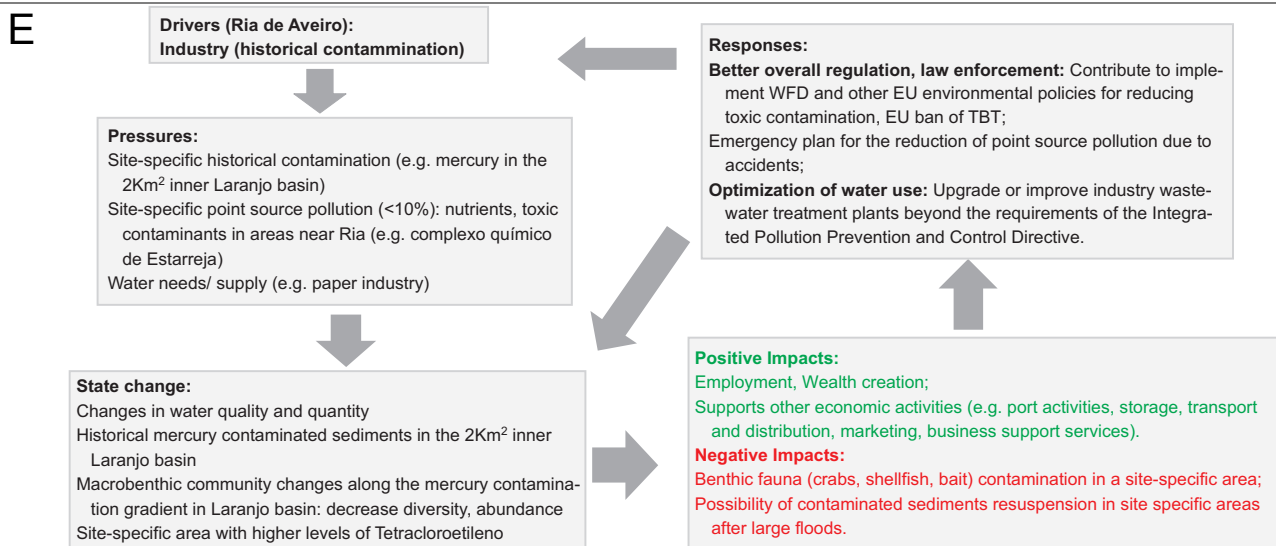


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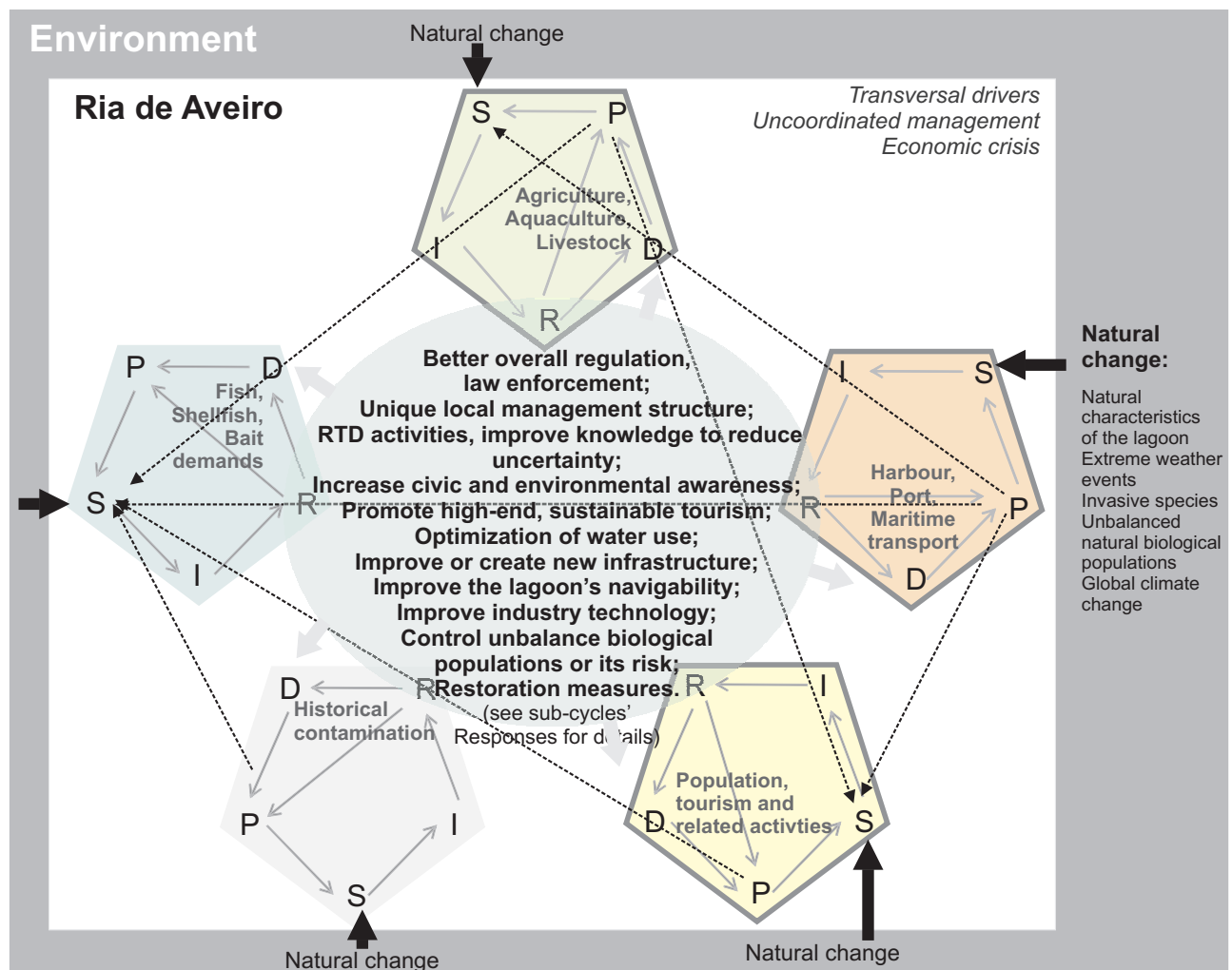


D





Supplementary Figure S1. DPSIR cycles for the *drivers* of Ria de Aveiro. A) Population, tourism and related activities; B) Aquaculture, agriculture and livestock; C) Harbour, port and maritime transport; D) Fish, shellfish and bait catches; E) Historical contamination associated to the mercury industry.

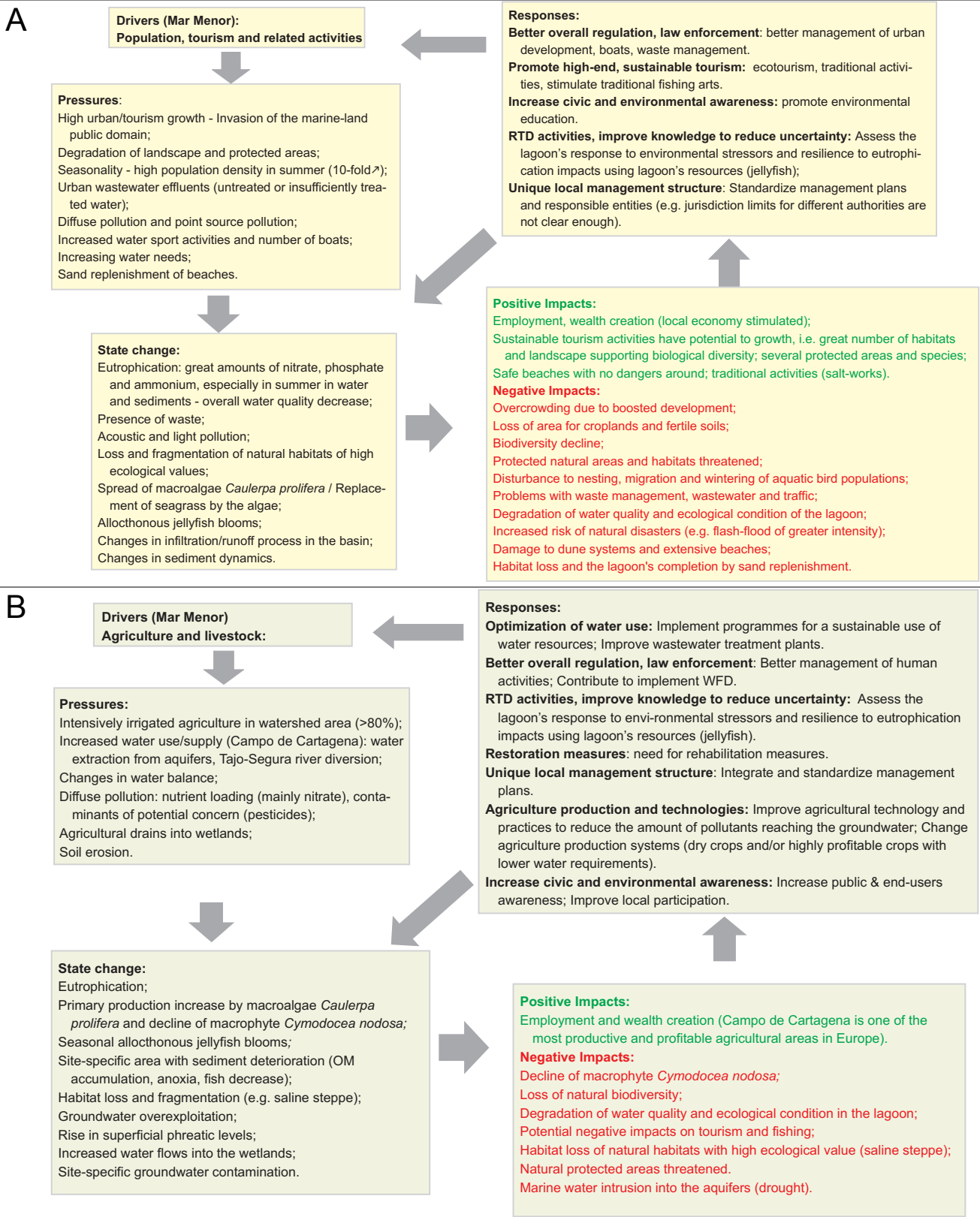


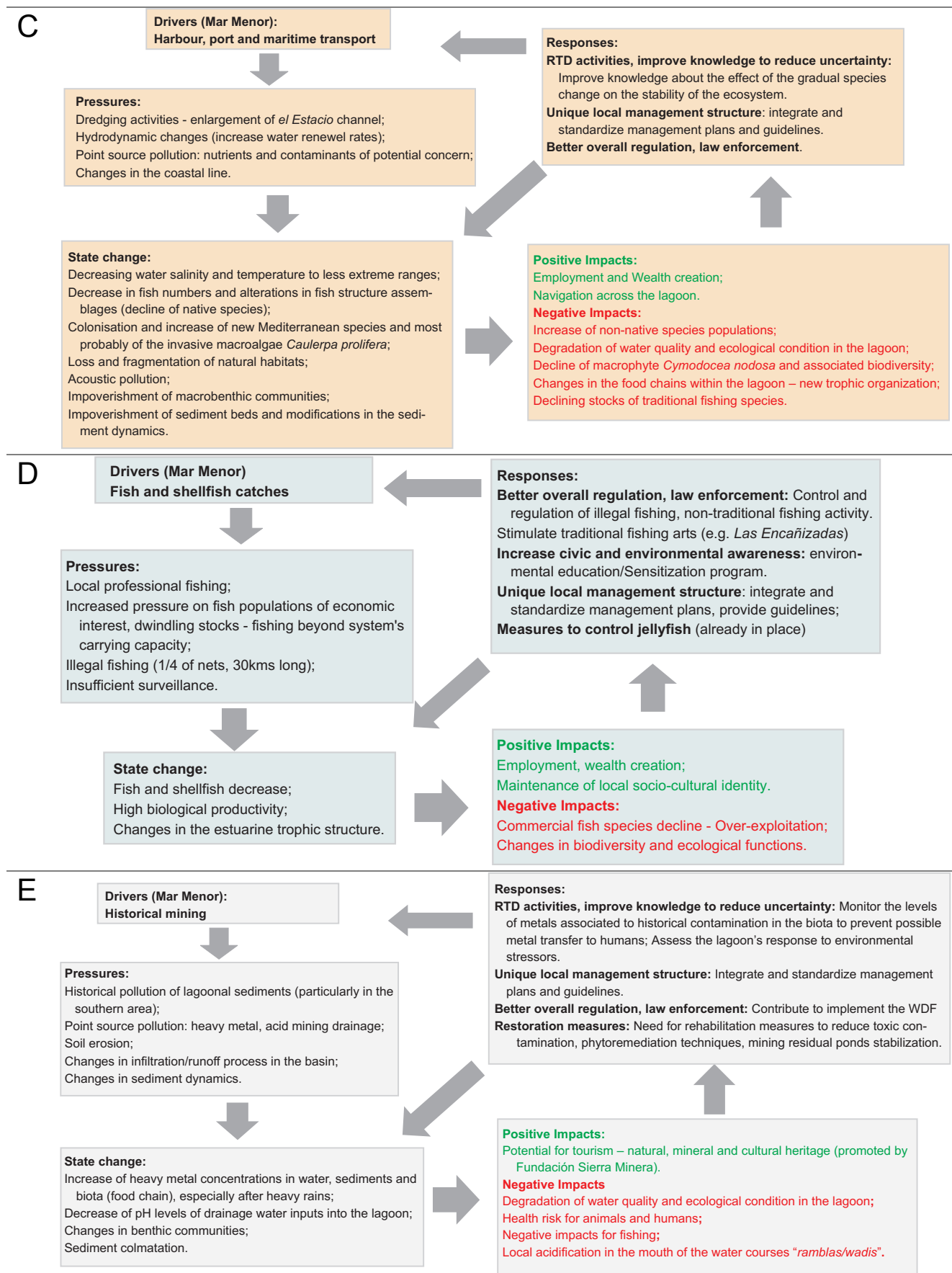
Supplementary Figure S2. Mosaic-DPSIR for Ria de Aveiro, with emphasis on the *drivers* with higher social-economical expression in the lagoon, showing interactions among DPSIR cycles (dotted arrows), the influence of the natural change on the *state* (black arrows) and that *responses* from each cycle should be combined into common integrated *responses*.

DPSIR data from Ria de Aveiro available in the following references:

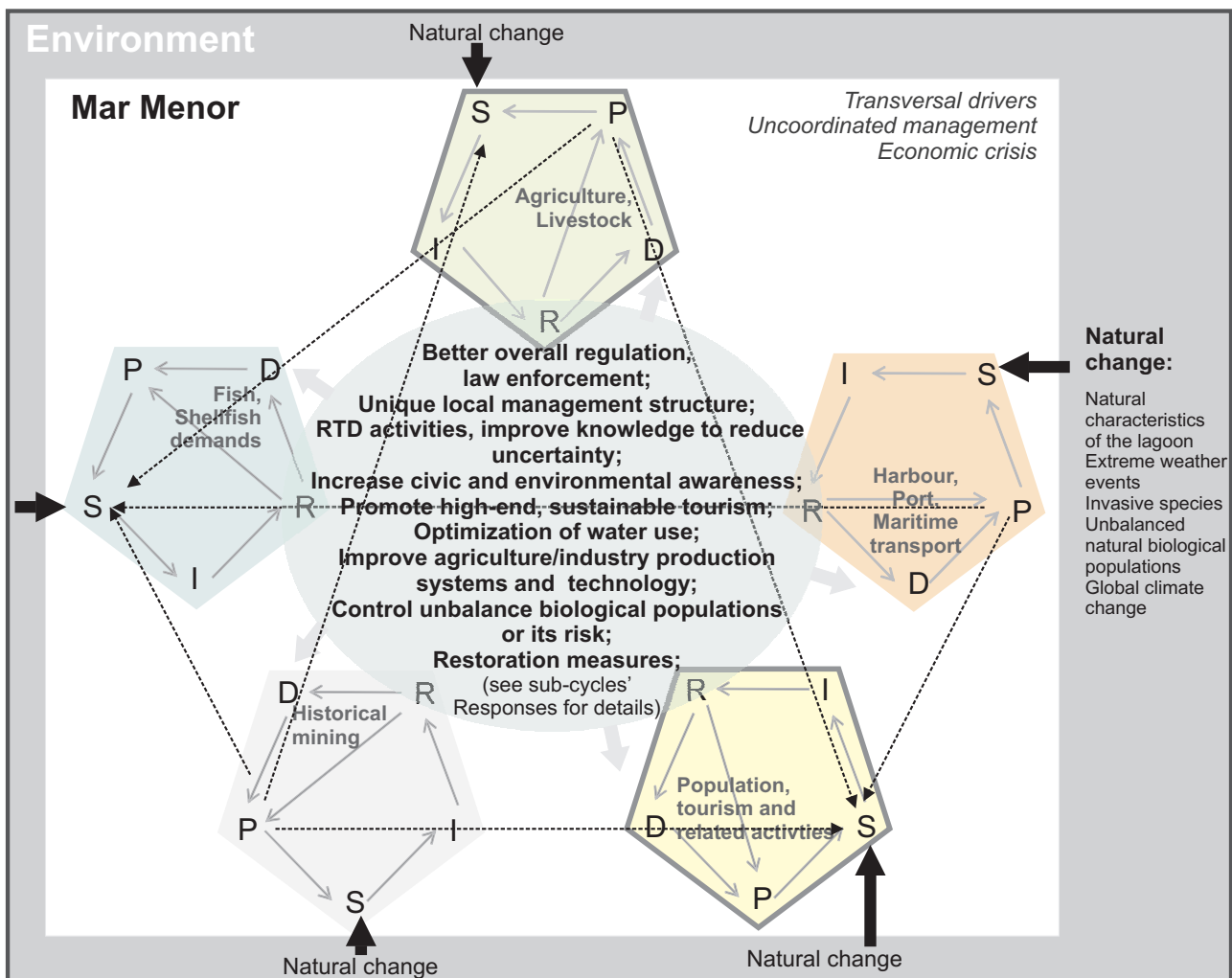
- Azevedo, A., *et al.*, Application of the generic DPSIR framework to seagrass communities of Ria de Aveiro: a better understanding of this coastal lagoon. *J Coast Res* **65**, 19–24 (2013)
- LAGOONS. The Ria de Aveiro Lagoon - Current knowledge base and knowledge gaps. LAGOONS Report D2.1b. 52pp. (2012) Available in <http://lagoons.biologiaatua.net>
- LAGOONS. Results of the problem based science analysis: The Ria de Aveiro Lagoon. *LAGOONS Report D3.2.1*. 50 pp. (2013) Available in <http://lagoons.biologiaatua.net>
- LAGOONS. Grupos de Discussão - Ria de Aveiro, Portugal. LAGOONS Destaque B4.1. 4pp. (2013) Available in <http://lagoons.biologiaatua.net> (in Portuguese)
- LAGOONS. Painel de Cidadãos - Ria de Aveiro, Portugal. *LAGOONS Destaque B4.2*. 3pp. (2013) Available in <http://lagoons.biologiaatua.net> (in Portuguese)
- LAGOONS. Activities report: Report on raising public participation and awareness including design of uptake and capacity building activities. *LAGOONS Report D4.1*, 61pp. (2014). Available in <http://lagoons.biologiaatua.net>
- Lillebø, A. I., *et al.* The Physio-geographical background and the Ecology of Ria de Aveiro. In Coastal Lagoons in Europe: Integrated Water Resource Strategies (Lillebø, A. I., Stalnacke, P. & Gooch, G. D.) (IWA Publishing, 2015)
- PGBH Plano de Gestão das Bacias Hidrográficas do Vouga, Mondego e Lis. Parte A – Avaliação Ambiental Estratégica. Relatório Ambiental, 445 pp. (2012a)
- PGBH Plano de Gestão das Bacias Hidrográficas do Vouga, Mondego e Lis. Parte 2 – Caracterização Geral e Diagnóstico. 6.2 – Relações entre o estado e as pressões que são responsáveis por este estado. (2012b)
- Sousa, L. P., *et al.*. Incorporation of Local Knowledge in the Identification of Ria de Aveiro Lagoon Ecosystem Services (Portugal). *J Coast Res* **65**, 1051–1056 (2013).
- Sousa, L. P., *et al.* The Management Story of Ria de Aveiro. In Coastal Lagoons in Europe: Integrated Water Resource Strategies (Lillebø, A. I., Stalnacke, P. & Gooch, G. D.) (IWA Publishing, 2015).

Mar Menor





Supplementary Figure S3. DPSIR cycles for the *drivers* in Mar Menor. A) Population, tourism and related activities; B) Agriculture and livestock; C) Harbour, port and maritime transport; D) Fish and shellfish catches; E) Historical mining (e.g. lead, zinc and iron).

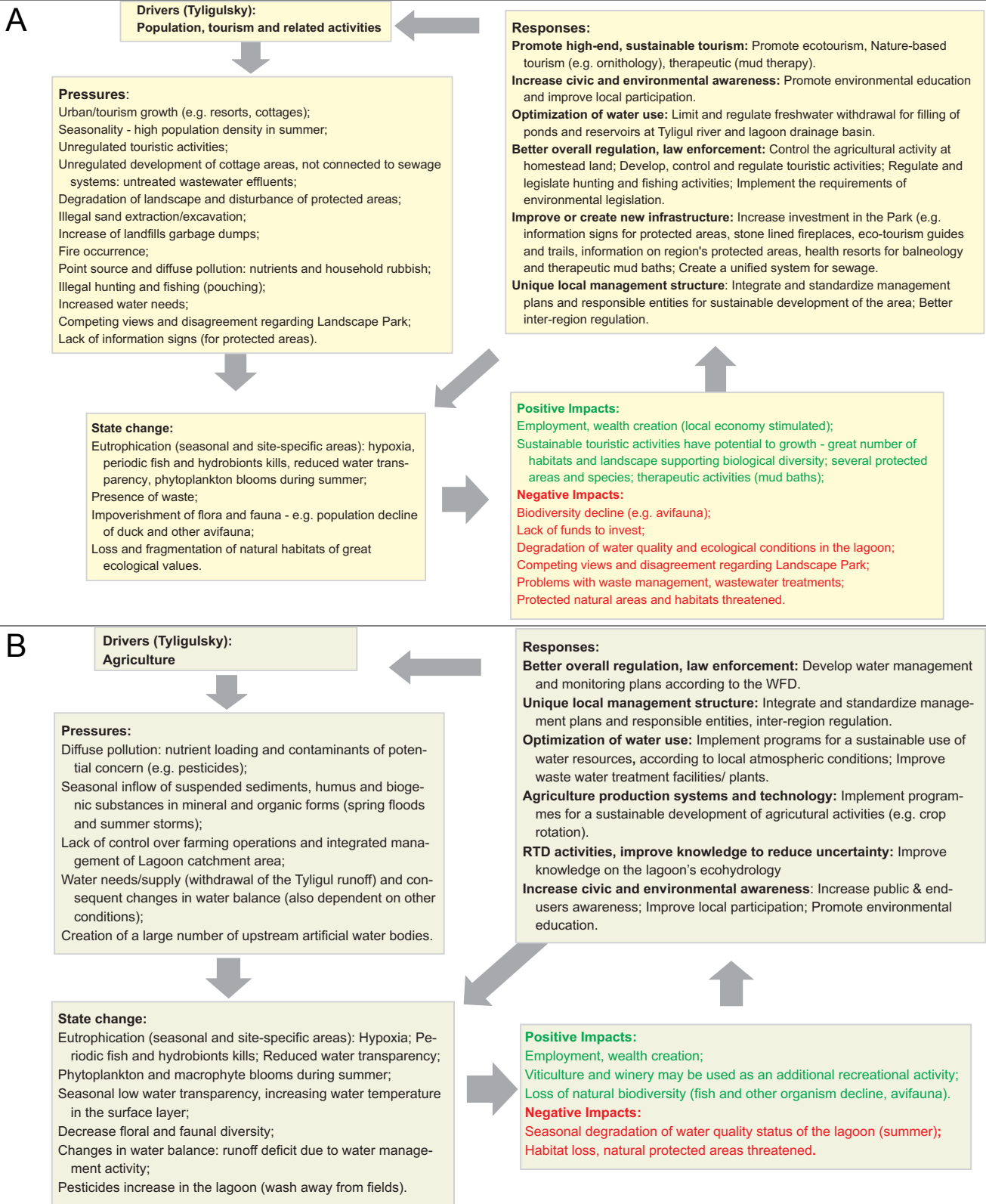


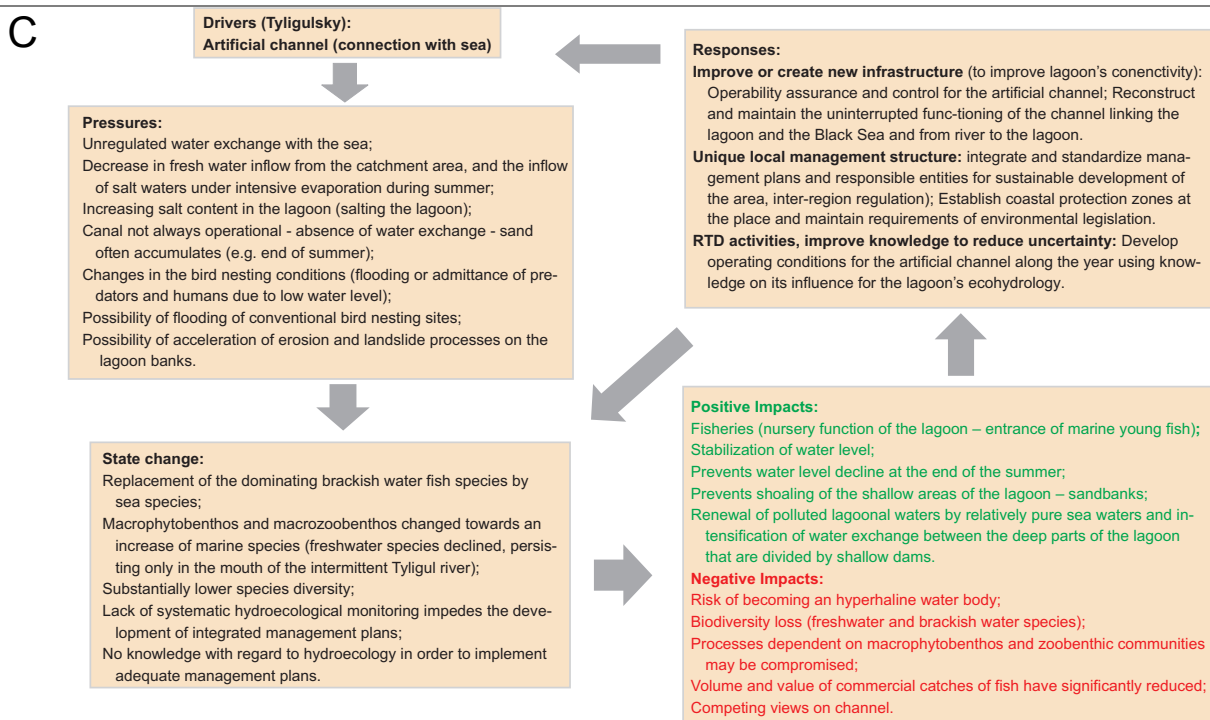
Supplementary Figure S4. Mosaic-DPSIR for Mar Menor, with emphasis on the *drivers* with higher social-economical expression in the lagoon, showing interactions among DPSIR cycles (dotted arrows), the influence of the natural change on the *state* (black arrows) and that *responses* from each cycle should be combined into common integrated *responses*.

DPSIR data from Mar Menor available in the following references:

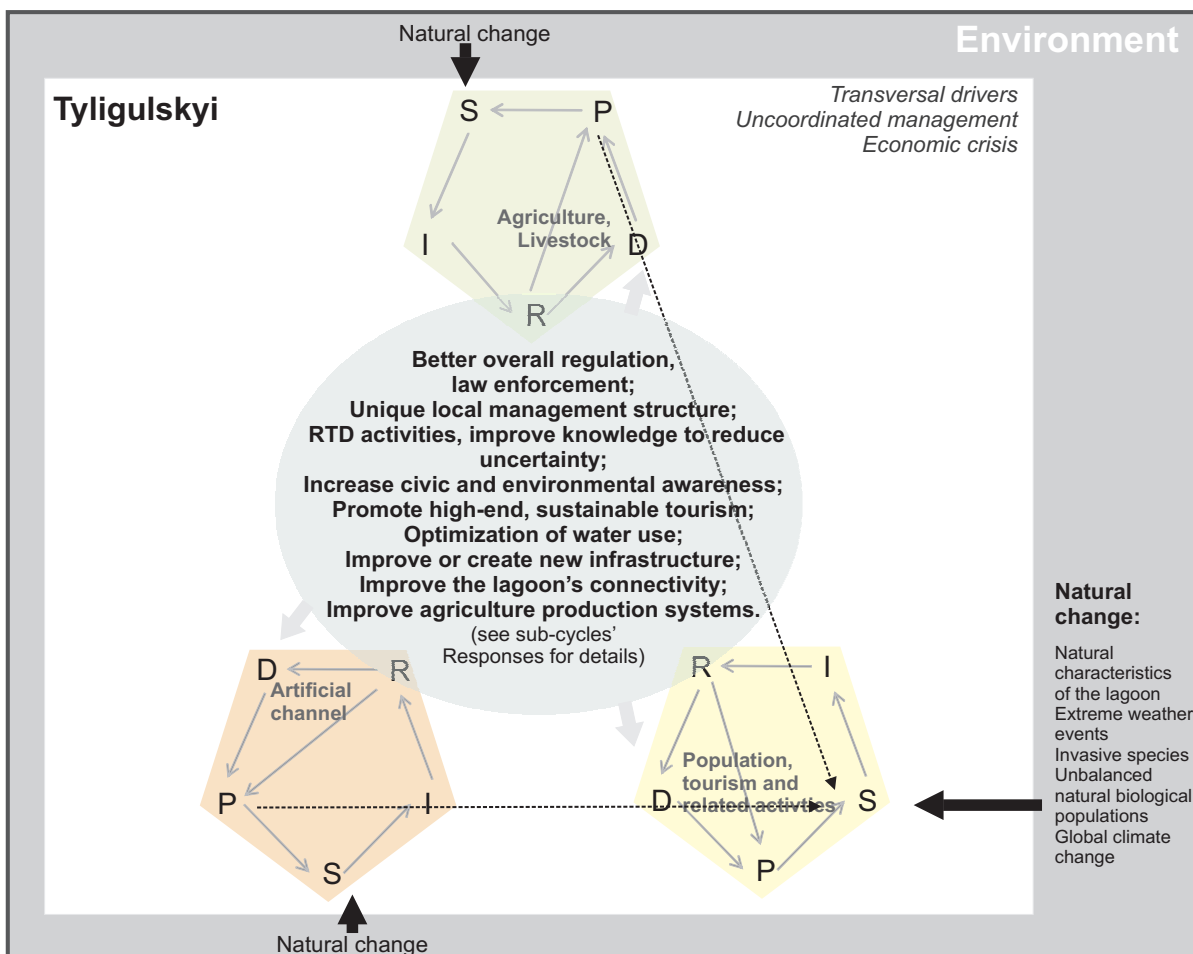
- LAGOONS. The Mar Menor - Current knowledge base and knowledge gaps. *LAGOONS Report D2.1c*. 65pp. (2012) Available in <http://lagoons.biologiaatua.net>
- LAGOONS The Mar Menor Lagoon, Spain. *LAGOONS Technical Brief TB3*. 5pp. (2012) Available in <http://lagoons.biologiaatua.net>
- LAGOONS. Results of the problem based science analysis: The Mar Menor. *LAGOONS Report D3.2.2*. 50 pp. (2013) Available in <http://lagoons.biologiaatua.net>
- LAGOONS. Grupos de Discusión – Mar Menor, España. *LAGOONS Resúmen B4.1*. 4pp. (2013) Available in <http://lagoons.biologiaatua.net> (in Spanish)
- LAGOONS. Activities report: Report on raising public participation and awareness including design of uptake and capacity building activities. *LAGOONS Report D4.1*, 61pp. (2014). Available in <http://lagoons.biologiaatua.net>
- Lloret J., *et al.*, The Management Story of Mar Menor. In *Coastal Lagoons in Europe: Integrated Water Resource Strategies* (Lillebø, A. I., Stalnacke, P. & Gooch, G. D.) (IWA Publishing, 2015)
- Marín A., *et al.*, The Physio-geographical Story of Mar Menor. In *Coastal Lagoons in Europe: Integrated Water Resource Strategies* (Lillebø, A. I., Stalnacke, P. & Gooch, G. D.) (IWA Publishing, 2015)

Tyligulsky Liman Lagoon





Supplementary Figure S5. DPSIR cycles for the *drivers* in the Tyligulskyi Liman Lagoon. A) Population, tourism and related activities; B) Agriculture and livestock; C) Artificial channel.

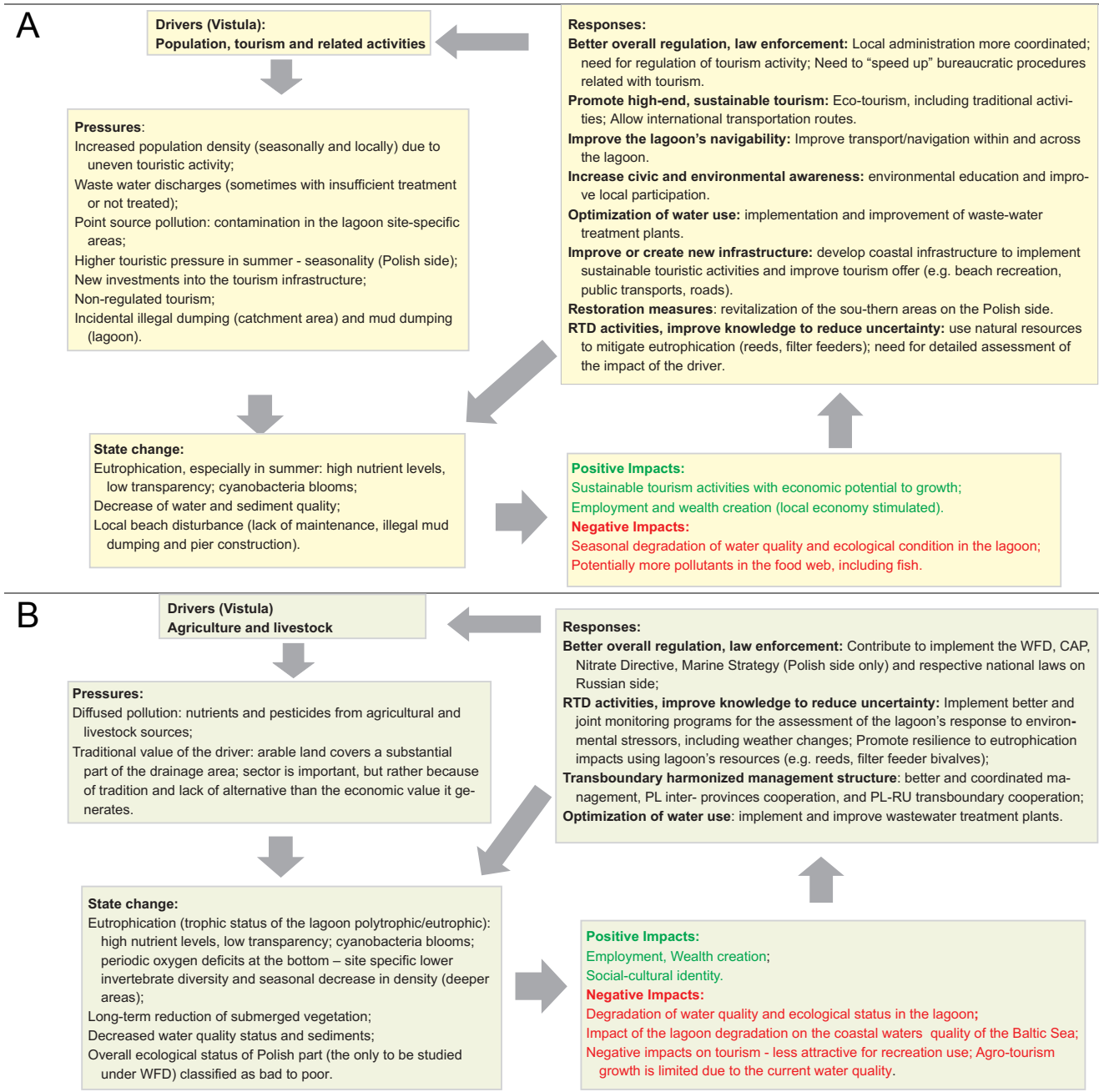


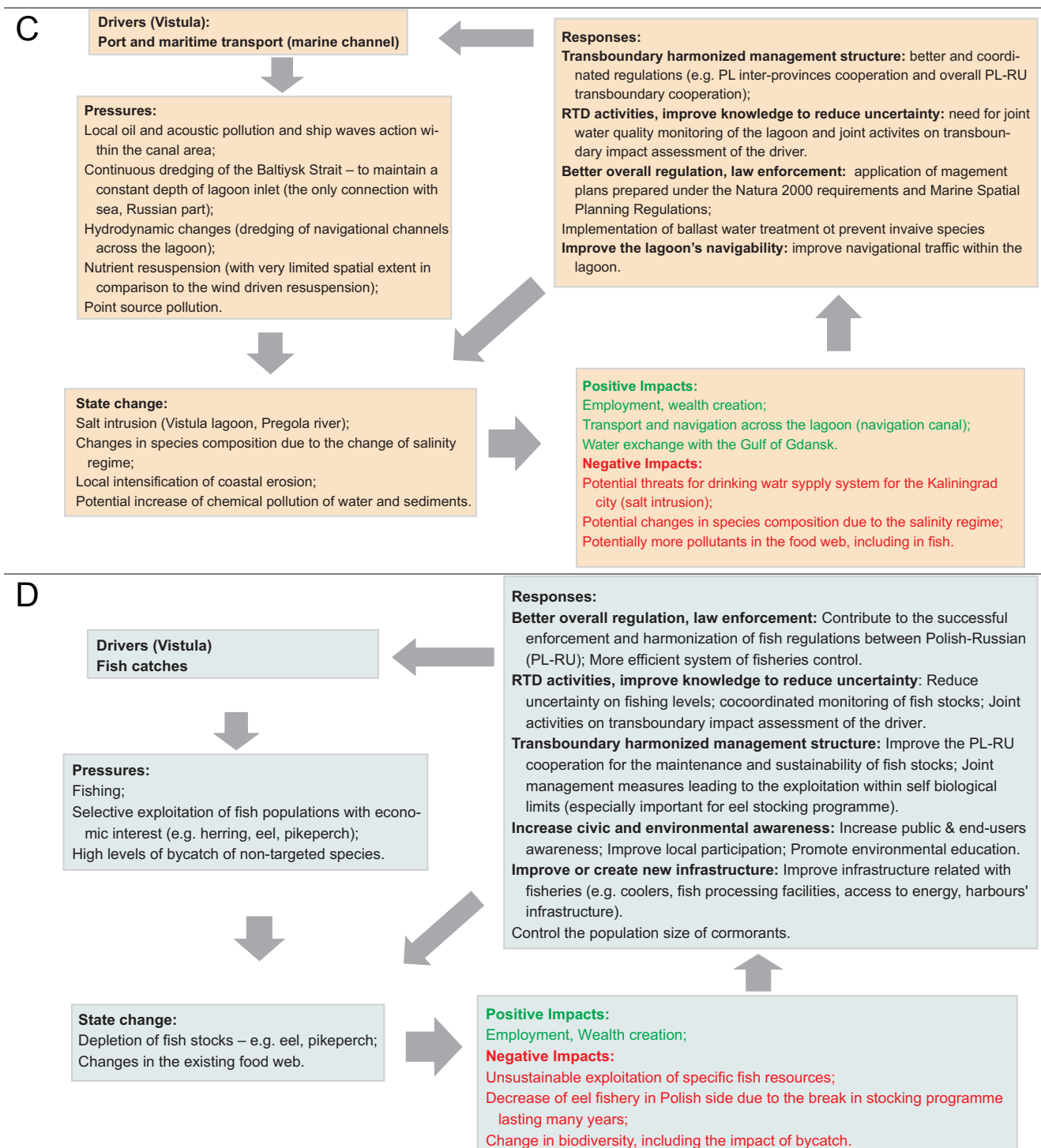
Supplementary Figure 6S. Mosaic-DPSIR for the Tyligulskyi Lagoon, with emphasis on the *drivers* with higher social-economical expression in the lagoon, showing interactions among DPSIR cycles (dotted arrows), the influence of the natural change on the *state* (black arrows) and that *responses* from each cycle should be combined into common integrated *responses*.

DPSIR data from the Tyligulsky Lagoon available in the following references:

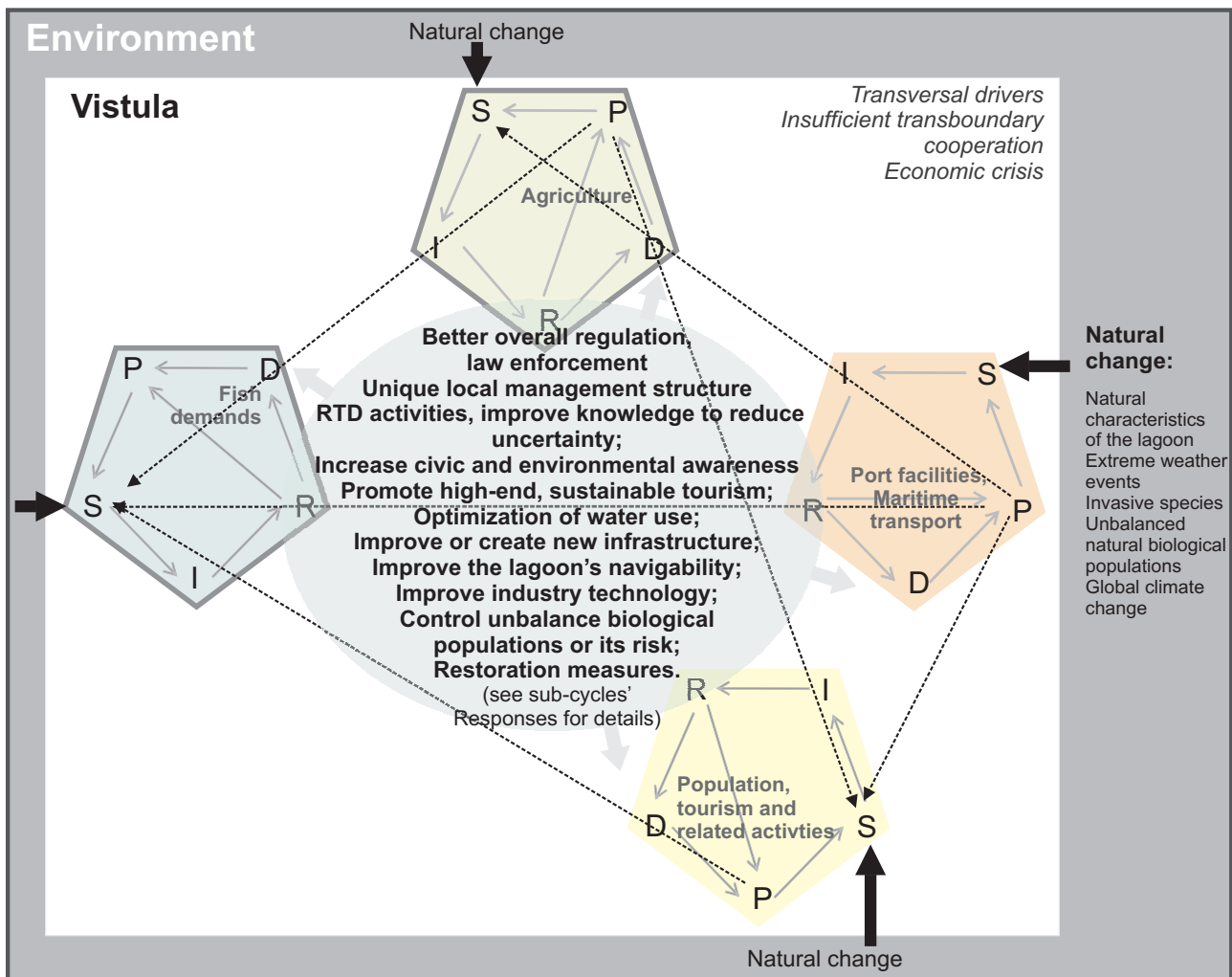
- LAGOONS. The Tyligulski Lagoon. Current knowledge base and knowledge gaps. LAGOONS Report D2.1d. pp. (2012) Available in <http://lagoons.biologiaatua.net>
- LAGOONS. The Tyligulskyi Lagoon, Ukraine. *LAGOONS Technical Brief TB4*. 5pp. (2012) Available in <http://lagoons.biologiaatua.net>
- LAGOONS. Results of the problem based science analysis: the Tyligulski Lagoon, Ukraine. *LAGOONS Report D3.2.3*. (2013) Available in <http://lagoons.biologiaatua.net>
- LAGOONS. Activities report: Report on raising public participation and awareness including design of uptake and capacity building activities. *LAGOONS Report D4.1*, 61pp. (2014). Available in <http://lagoons.biologiaatua.net>
- Gubanova, O., *et al.* The Management Story of Tyligulskyi Liman. In Coastal Lagoons in Europe: Integrated Water Resource Strategies (Lillebø, A. I., Stalnacke, P. & Gooch, G. D.) (IWA Publishing, 2015).
- Tuchkovenko Y, Loboda N, Khokhlov V. The physio-geographical background and the ecology of Tyligulskyi Liman Lagoon. In Coastal Lagoons in Europe: Integrated Water Resource Strategies (Lillebø, A. I., Stalnacke, P. & Gooch, G. D.) (IWA Publishing, 2015).

Vistula Lagoon





Supplementary Figure S7. DPSIR cycles for the *drivers* in the Vistula Lagoon. A) Population, tourism and related activities; B) Agriculture and livestock; C) Port and maritime transport; D) Fish catches.



Supplementary Figure S8. Mosaic-DPSIR for the Vistula Lagoon, with emphasis on the *drivers* with higher social-economical expression in the lagoon, showing interactions among DPSIR cycles (dotted arrows), the influence of the natural change on the *state* (black arrows) and that *responses* from each cycle should be combined into common integrated *responses*.

DPSIR data from the Vistula Lagoon available in the following references:

- Bielecka, M., Różyński, G. Management conflicts in the Vistula Lagoon area. *Ocean Coast Manage*, **101**, 24-34 (2014)
- LAGOONS The Vistula Lagoon – Current knowledge base and knowledge gaps. LAGOONS Report D2.1a. 99pp. (2012) Available in <http://lagoons.biologiaatua.net>
- LAGOONS The Vistula Lagoon, Poland-Russia. LAGOONS *Technical Brief* TB1. 8pp. (2012)
- LAGOONS Results of the problem based science analysis: The Vistula Lagoon. LAGOONS Report D3.2.4 35 pp. (2013) Available in <http://lagoons.biologiaatua.net>
- LAGOONS Grupy Fokusowe – Zalew Wiślany, Polska-Rosja. Biuletyn Proj. LAGOONS, B4.1., 4pp. (2013) Available in <http://lagoons.biologiaatua.net>
- LAGOONS Activities report: Report on raising public participation and awareness including design of uptake and capacity building activities. LAGOONS Report D4.1, 61pp. (2014) Available in <http://lagoons.biologiaatua.net>
- Różyński, G., *et al.* The Physio-geographical Story of Vistula Lagoon. In Coastal Lagoons in Europe: Integrated Water Resource Strategies (Lillebø, A. I., Stalnacke, P. & Gooch, G. D.) (IWA Publishing, 2015).
- Różyński, G., *et al.* The Management Story of Vistula Lagoon. In Coastal Lagoons in Europe: Integrated Water Resource Strategies (Lillebø, A. I., Stalnacke, P. & Gooch, G. D.) (IWA Publishing, 2015).