Case study

#20 Dolphinfish in the north-west Mediterranean

#21 Sardines and anchovies in the Bay of Biscay

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Species background and economics

The Dorado, Llampuga or Dolphinfish (Coryphaena hippurus) is a tropical/subtropical large migratory species whose northern-most distribution is the Mediterranean Sea, where it enters from the Atlantic waters in spring to spawn. Dolphinfish inhabits surface waters and grows very rapidly.

It is fished as a juvenile in August-November by an artisanal fishery using Floating Aggregation Devices and special surrounding nets, mainly in Malta, Italy, Tunisia and Spain (the Balearic Islands). Adults are by-catch of the of the surface long-line fishery. In the Balearic Islands, it is the most important fish in terms of landed weight for the small-scale fleet (345, ~7-m boats in 2010, Fig.1).

Average catches tend not to exceed 80kg per trip. Maximum revenues of the fishery are around €45,000 per month during the fishing season.

In other countries such as Malta or Italy, however, revenues and employment from this traditional fisheries are much larger. As an appreciated fish of the season since ancient times, it has a profound cultural value in these places.

Expected projections under climate change

The NW Mediterranean Sea is projected by the IPCC to be warmer (Fig.2), more stratified, and to receive less river runoff. Sea Surface Temperature (SST) is projected to increase by approximately 0.6°C in 2040-2060 under a mitigation-based emissions scenario (RCP 4.5) and up to 2.5°C in 2080-2099 under the business-as-usual (RCP 8.5) scenarios.

At the end of the century, peak increases in temperature will occur during the hottest months, in August and September, with differences of almost 4°C at the end of the century under RCP 8.5 (Fig.2).

These within-year differences may be particularly important because different life stages (for example, larvae, juveniles) occur in different months and can cope with different thermal ranges.

Moreover, the reproduction period may be affected as a response to changes in the seasonality.

Scenarios describing future society and economy

CERES uses models to estimate economic developments in Europe's fishery and aquaculture based on select, pre-defined physical and socio-economical future scenarios.

These future scenarios were specified by industry partners and stakeholders in the first year of CERES (e.g. fish prices, fuel prices, technological advancements, regional policy issues, etc.).

'World Markets'	'National enterprise'
• Personal independence, high mobility and consumerism • Reduced taxes, stripped-away regulations • Privatised public services • High fossil fuel dependency • Highly engineered infrastructure and ecosystems	• National isolation and independence • Protection of national industry • High resource intensity and fossil fuel dependency • Low investment in technological development and education • Low priority for environmental protection
'Global sustainability'	**'Local stewardship'**
• High priority for welfare and environmental protection • Cooperative local society • Intense international cooperation • Increased income equality • Low resource intensity and fossil fuel dependency	• Promotion of small scale and regional economy • Less attention for global (environmental) problems • Moderate population growth • Income of industrialised and developing countries converge • No overarching strategy to manage ecosystems

Table 1 Outline of the four social-political scenarios developed by CERES partners and stakeholders

Socio-economic effects

CERES uses four scenarios to make projections of the potential social and economic impacts of climate change. Scenarios are imagined, yet plausible 'futures' that are both optimistic or pessimistic, based on available projections for gas concentration, cost of life, population growth, urbanisation etc., plus informed guesses of plausible socio-political scenarios (SSPs: legal and social frameworks that foster, for example, the protection of single nations welfare, or that act to maintain a global good conservation status of food sources, etc).

In the case of dolphinfish, the Local Stewardship (RCP 6.0 & SSP2) scenario focuses on conservation efforts to preserve coastal habitats used by juvenile dolphinfish for feeding. Better control over coastal fishing practices would improve resource status, but dolphinfish out of coastal artisanal fisheries' reach would not be effectively managed. Self-regulation of artisanal fishery and policy incentives for local consumption would benefit the fishery.

In this scenario we speculate with a potential 10% increase in catches. In the World Markets (RCP 8.5 & SSP5) scenario, a decline in apex predators of high value (e.g. tuna, valued demersal fish) could increase prey available to adult dolphinfish.

Alternatively, by-catch mortality from uncontrolled longliners could increase the competitiveness of large fishery enterprises that may inundate local markets (decreasing price) and blur local cuisine traditions, thus affecting the demand for dolphinfish. The value of dolphinfish would be translated to recreational fishers. We speculate with a 10% decrease in catches, driven by the artisanal fishermen, in order to keep profits.

Under the National Enterprise (RCP 8.5 & SSP3), environmental degradation and fishing effort would be contained at levels similar to current ones. Artisanal fishing activities may benefit because they provide a relatively large number of jobs and because exports and imports are economically discouraged. Conflicts over the resource property could arise because of the high mobility of this species which represents a shared resource. Recreational fisheries would be reduced and national labelling schemes focusing on sustainability would exist.

A potential legal extension of the fishery period is contemplated. Global Sustainability (RCP 4.5 & SSP1) would probably reduce fishing effort on many species, with uncertain consequences on dolphinfish. Assessment of dolphinfish would be compulsory, and catch quotas implemented by the EU.

Inter-country management plans in the Western Mediterranean would be enforced. Reduced fishing pressure on spawners might increase the size of the stock. Artisanal fishers will be well paid because the fishery is sustainable (takes on juveniles) and extremely selective, with almost null discards. Ecolabelling would add to these advantages.

Figure 1 Coryphaena hippurus images of juvenile dolphinfish (top-right and bottom) and adult (top-left). *Pictures by V. Moltó, A. Álvarez and I. Catalán.*

Key research needs

There is a large gap in knowledge on the spatial distribution of the various life stages of dolphinfish, from eggs to adults, as well as how environmental factors affect fish reproduction, spatial distribution and growth rate.

To make better projections of the effects of climate change on dolphinfish, CERES focused on generating fundamental knowledge, including:

• What are the environmental constraints for spawning and growth?

• How may the spawning season and area of spawning change in the face of climate change?

• How will fish growth rate change in the different climate change scenarios?

• What are the social and economic consequences of different climate change scenarios on this fishery and how can dependent human communities adapt to these changes?

CERES research

- Compiled physiological and population-based information relating potential climate change effects (temperature, acidification, etc.) on the biology of this species as part of a gap and meta-analysis of commercially important fish and shellfish in European waters.
- Engaged stakeholders from the Regional Government, commercial and recreational fishers and the general public to explain goals, to regionalise scenarios and to co-develop social-ecological research on climate change issues.
- Compiled fisher's data on catch locations of spawning adults (jointly with FAO regional programs) and compiled juvenile growth and environmental data.
- Constructed habitat suitability relationships and models for juvenile growth based on temperature and photoperiod and the seasonal timing of adult spawning based on temperature.
- Projected the biological consequences of different climate change scenarios on fish growth rate and spawning timing and the length of the fishing season.
- Developed a model linking biological projections with economic consequences, Bayesian Belief Networks.
- Mapped the potential factors influencing the socio-economics of this fishery and have proposed solutions in collaboration with stakeholders.

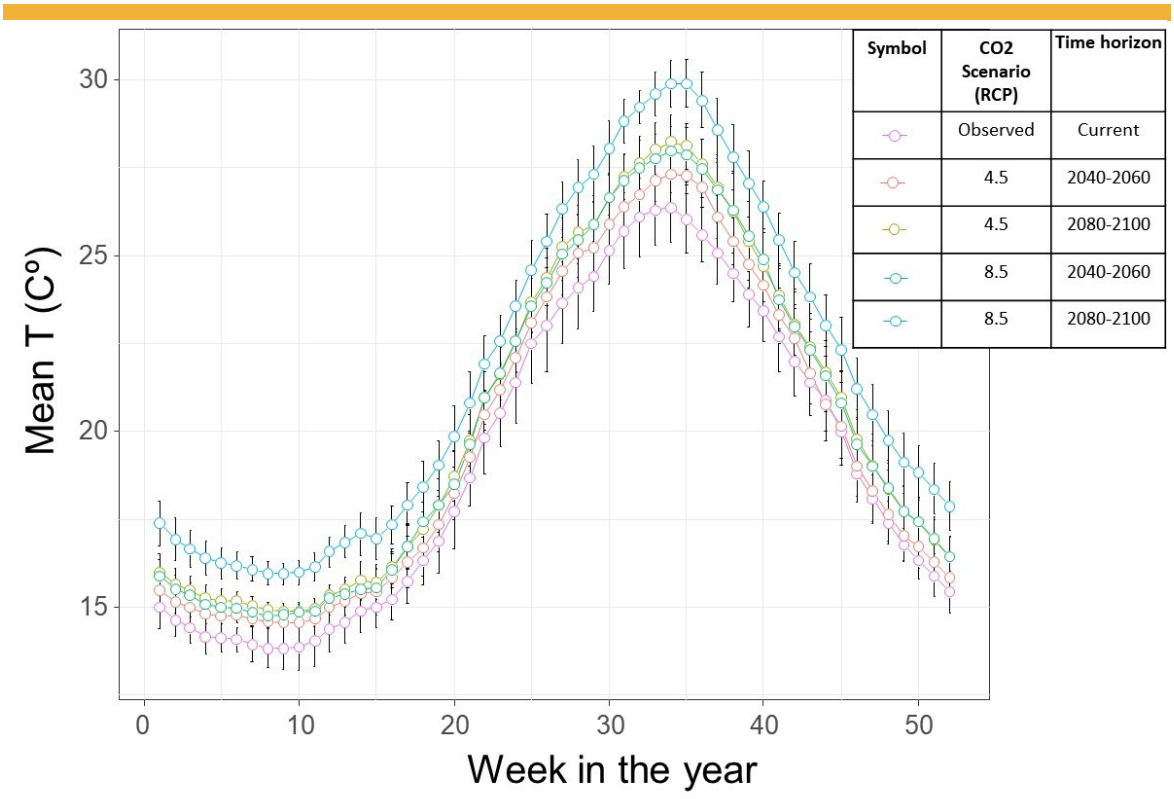
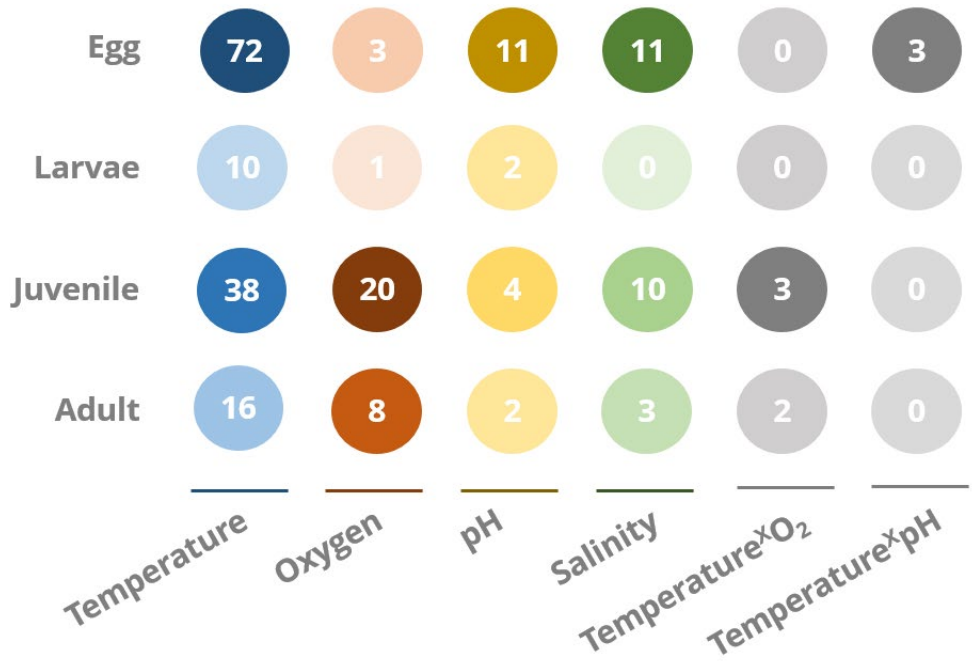


Figure 2 Observed average temperature in the spawning grounds around the Balearic Islands and projected changes under different CO_2 concentration scenarios across two time horizons. *Image: I. Catalán.*

Results

Research published on finfish in European seas



- No data set was found for Dolphinfish and only one study outside Europe was found.
- The one study outside Europe analysed the effect of temperature on growth.

Biological consequences

Little is known on the potential direct effects of climate change on dolphinfish. Winter water temperatures (T < 18°C) are physiologically sub-optimal for this species, leading to seasonal migration for feeding and spawning.

In areas of similar latitudes to the Mediterranean but warmer during most of the year (e.g., the Gulf of Mexico), this species is present and spawns all year round.

We collected data from the literature (growth rates, reproductive months and average size of reproduction, physiological limits) and we compiled and analysed new spatial data (10 years) coming from the bycatch of longline fisheries, as well as individual age and length data from over 2000 individuals from four Mediterranean countries.

These data were used to build new models on thermal effects on life-history traits.

During the fishing season (August 25 to end of December), increases in SST associated with RCP 8.5 would increase the average length of vulnerable (here defined as >20 cm furcal length) juvenile dolphinfish by about 25 % by 2100 (Figure 3, left). Smaller increases are expected in RCP 4.5, with more moderate warming.

The spawning probability is expected to increase both in latitude and longitude, making dolphinfish more accessible to fishers (Figure 3, right).

Current areas where the Mediterranean dolphinfish fishery are productive and traditional (Balearic islands, Malta, Sicily, Tunisia) are projected to either remain the same or to benefit from increased warming

(Figure 3) although biotic (indirect) effects of climate change have not yet been included in models.

Predicted extreme warming at the end of the century, however, will result in lower beneficial effects than moderate warming under RCP 4.5

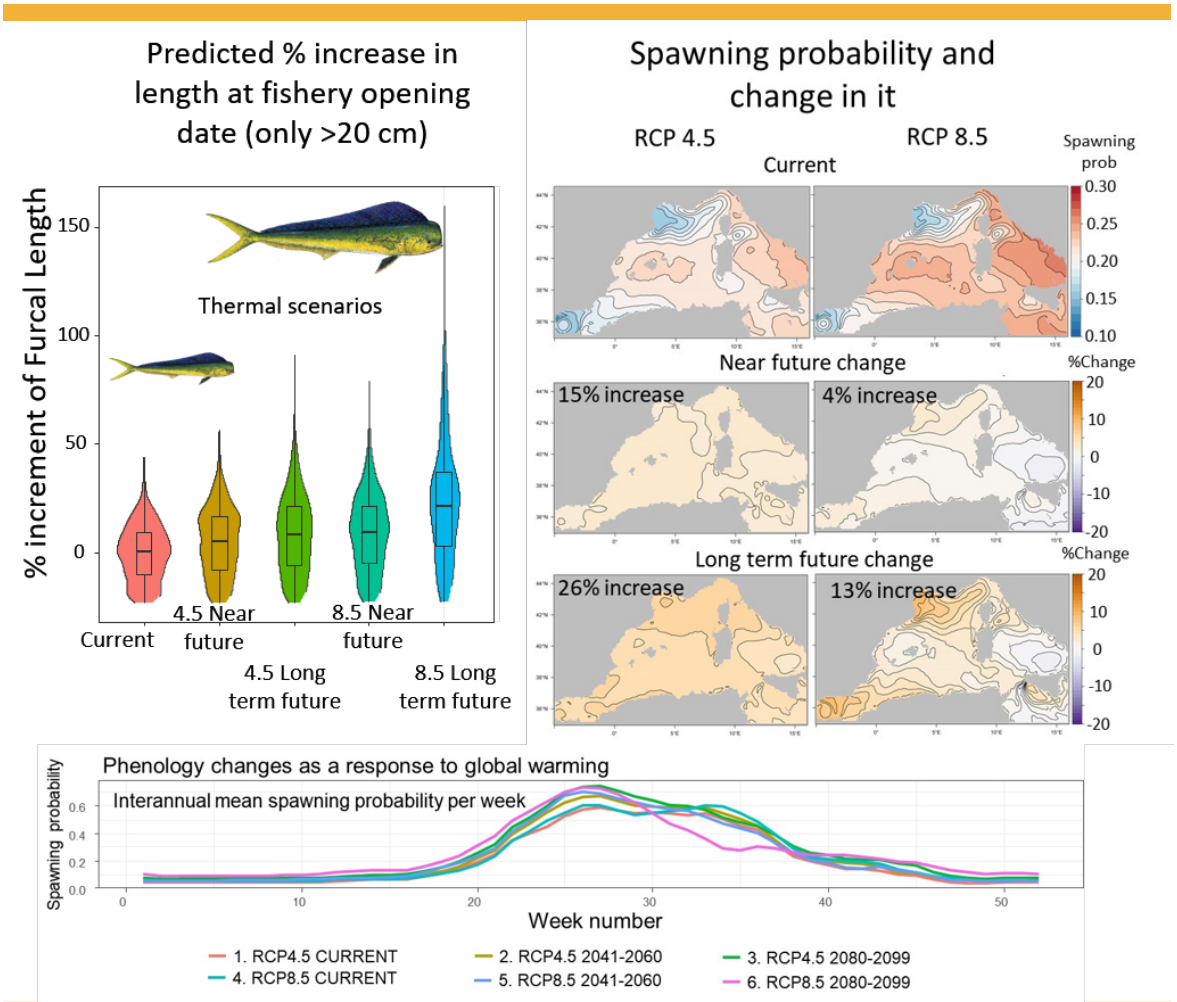


Figure 3 Top left: predicted evolution of change in dolphinfish size (furcal length) at the current opening date of the fishery (August 25) in the Balearic Islands, under different future scenarios. Top right: Predicted spawning probability (and its change) in current, near future and long term future under two RCP scenarios. The inner % represent the average expected increase in spawning probability. Note that units in the right maps are not the same in each scenario. Bottom: Observed and predicted spawning probability for each week in an average year in the different scenarios.

Economic consequences

Due to the lack of proper data for formal bio-economic projections, we conducted a Bayesian Believe Network (BBN) to resolve potential economic impacts in the different scenarios.

We built a Bayesian Belief Network (BBN) to determine the influence of preponing the opening the fishing season and altered landings due to assumed changes in demand on profits, as well as to display the main components of the dolphinfish fishery. These fully quantified components include the output from the biological model, management options, fisheries yields and economic variables, all based on national statistics.

The CERES scenarios were extended to include stakeholder input on likely future alterations in landings and the opening date of the fishing season. The latter was advanced by two weeks in the National Enterprise scenario.

Landings were assumed to decrease by 10% in the World Markets, and to increase 10% in the Local Stewardship, but remained the same in the other scenarios.

In all scenarios, we used nominal prices hence labour costs were corrected for inflation by an annual increase of 2%. We used fish and fuel price projections from 2015 to 2050, with three levels (low, medium & high) per scenario (hence 12 BBN runs).

The main results from the BBN for 2050 suggest:

- Fish price has a large impact on future profits while the impact of fuel prices is comparatively low.
- The projected ecological changes, when linked to preponing the fishing season by two weeks, produce slight changes in seasonal profits from 12% to 16%.
- If low increases in price are simulated, profits change from -3% (World markets) to 39% the current profits (National Enterprise)
- If high price increase are contemplated, profits range from 137% (Global sustainability to 241% (Local sustainability)
- The uncertainty in these numbers is high; standard deviation ranges from 35% to 99%

Climate-ready solutions

Fisheries climate vulnerability was assessed across European countries (via sensitivity of species landed) and all 421 fleets (Europe only, via economic factors and diversity of catch).

Countries in the Western Mediterranean have an intermediate vulnerability based on the catch composition.

Artisanal fleets that target only a few species were more vulnerable than highly industrialised, mixed fisheries fleets

Fishers targeting dolphinfish may benefit from climate change but artisanal fleets have relatively low adaptive capacity if seasonal catches rely heavily on one species, which is the case.

The fishing method is sensible to bad weather (e.g. currents & wind), resulting in FAD loss or impeding gear deployment (surrounding net). Increase of bad weather events may impact the duration of the seasonal fishery. It is likely that the most extreme scenarios exceed, in some areas, the thermal limits of the species, which would modify the current spawning season to avoid the extreme heat peaks.

The studied fishery is located at its northern distribution limit, hence the probability that environmental changes affects distribution or phenology is higher.

The growth of this species is extremely high, attaining up to 70 cm in 6 months, the fishery targets only age-0 individuals and its vertical distribution is mostly confined to the first tens of meters. Therefore, even heat waves might affect the whole fishery in a particular year. We anticipate that increasing warming can affect the length of the spawning season and the growth of the fish. It is not unlikely that this species increases its presence through the year, and that the landed sizes and total catches vary in the coming decades.

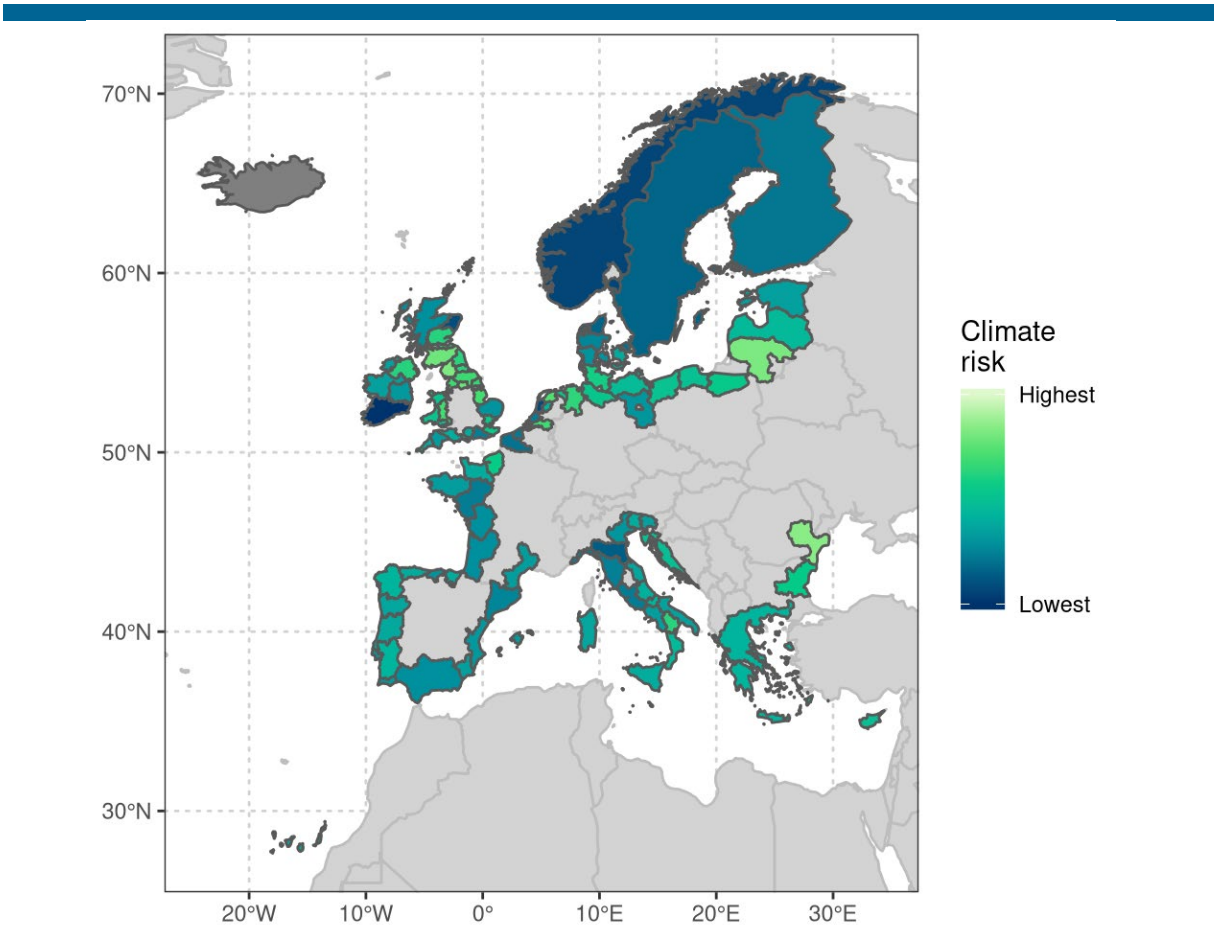


Figure 4 Regional climate risk. Colour scale is linear and presented without values, as they have little direct meaning. *Credit : Mark Payne*

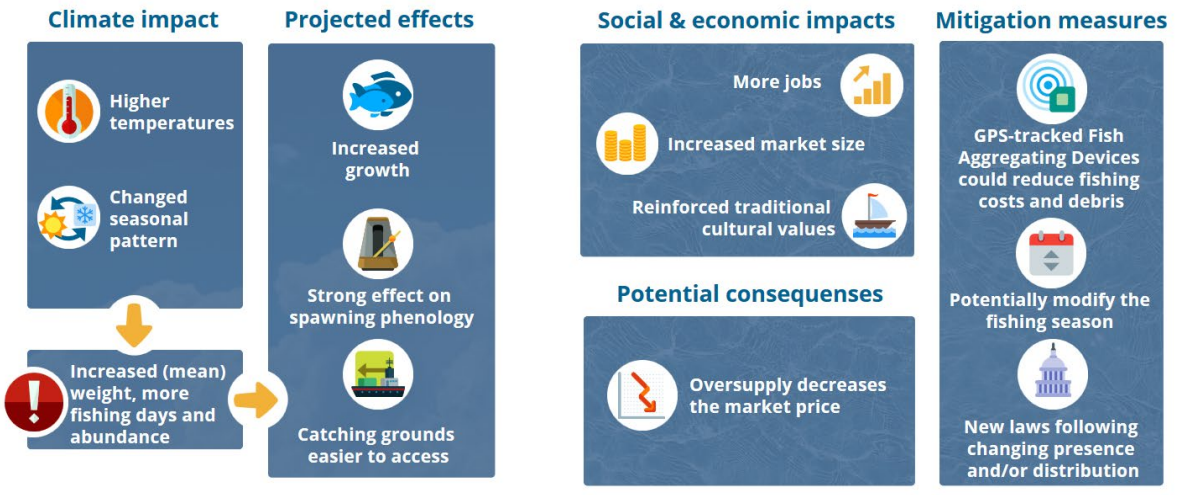


Figure 5 Bowtie analysis based on stakeholder contributions. Full bowtie can be found at http://bit.ly/CERESbowtieDolphinfish

This species in the Mediterranean Sea is an example of a potential 'winner' from climate change.

The Dolphinfish fishery is comprehensively managed at the local level, including measures such as a quota and licensing system and restrictions on how, when and where to fish. In a future climate, it is likely that the length of the fishing season can be slightly increased by two weeks.

Current self-managed daily catch quotas can help maintain convenient market prices, but their application must be effectively communicated to managers. The management system in place has thus far assured the commercial viability of the fishery and is likely equipped to reap climate changes induced benefits for the local fishery such as through the advancement of the opening of the fishing season. However, this will depend critically on the evolution of other factors (evolution of other target species, people consumption habits, market dynamics).

The strongest expected changes are therefore more dependent on social, political and marketing issues than on projected biological changes.

More knowledge on its population dynamics and stock status is needed to reduce the uncertainty in the models (ecological spatial data is urgently needed) and assess whether potential future increases in overall landings are within safe ecological limits.

Policy recommendations

Based on bowties & internal discussions, policy recommendations include:

- In a future climate, it is likely that the length of the fishing season can be slightly increased, but this will depend critically on the evolution of other factors (evolution of other target species, people consumption habits, market dynamics).
- Stock assessment of this species is required for better regulation of management. It is likely that multi-national agreements are needed in the future to manage this shared stock.
- New technologies could be applied to better estimate effort in the Floating Aggregation Devices.
- Estimates of the impact of recreational fishing are needed.
- Facilitate the certification, branding and marketing of dolphinfish while maintaining cultural heritage of the product.
- Provide incentives to increase the attractiveness of fishery jobs to young people.

Further reading

CERES publications:

Scientific papers

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