COST Action FA1004 *Conservation Physiology of Marine Fishes*
Minutes of the WG2 meeting
CNR IAMC Oristano Italy, May 30th-31st 2012

Organising Committee:

Paolo Domenici, David McKenzie, Myron Peck, Christian Jorgensen, Adriaan Rijnsdorp

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Objectives

The **objectives of this meeting** were to make progress in relation to WP2 and to integrate the various modeling approaches used in the literature with respect to ecological modeling and conservation physiology. The meeting started with a short introduction by Paolo Domenici (Action vice-Chair), who described the rationale for the meeting and the meeting programme. This introduction was followed by scientific presentations and by discussions. The discussions focused on integrating the various modeling efforts within the scope of conservation physiology, in order to discuss how physiology can be better used in modeling tools that can aid in the management of marine ecosystems. Current approaches to incorporating physiology range from models including none to others bursting with detail, and that consider everything from a single fish to global resources. We posed ourselves the question: Can we rise to the challenge of projecting future changes in distribution and productivity, assessing risks for local populations, or predicting and mitigating the spread of invasive species? Focusing on this issue, most of the meeting was devoted to drafting a discussion manuscript to be submitted to the journal Biology letters. The timetable of the meeting and a draft of the manuscript are shown below.

Programme:

Wednesday 30 May

9:00-11:00 Morning session (ecophysiologists /experimental ecologists – five 20 min presentations plus discussion)

11:00-11:15 Coffee break

11:15-13:00 Morning session (Jorgensen, Burrows, Huebert + discussion)

13:00-14:00 Lunch at IAMC-CNR

14:00-1600 Afternoon session (Peck, Cheung, Cucco, SInerchia + discussion)

16:00-16:15 Coffee break

16:15- 18:00 Afternoon session (Teal , Holt, discussion)

18:30 Transportation to Capo Mannu (20 minutes transportation from the residence Spinnaker)

20:00 Dinner "Sottovento" Taverna by Capo Mannu

Thursday 31 May

9:00-11:00 Morning session (discussion-Leading Jorgensen Peck: Pro and cons of tools presented- How can modeling be used for the eco-physiological questions posed so far)

11:00-11:15 Coffee break

11:15-12:30 Morning session (Leading, Jorgensen Peck McKenzie, A plan of action for integration)

To remind ourselves, aims from the COST proposal include:

• *"Evaluate current and forecast future species distributions with models that explicitly incorporate physiological processes*

• *Explore the linkages between physiology, population dynamics, ecology and distribution."*

12.30-14:45 Transportation (15 minutes) and lunch at "Tharros" (short visit of the Sinis Marine Protected Area)

14:45-16:00 Afternoon session (Leading Jorgensen, Peck- where we want to go with Cost action and the tools we have)

Focus on deliverables from the COST proposal include:

"At least 3 literature reviews based upon the integration of data and ideas, to incorporate physiological processes into modelling climate change effects on fishes. Topics include

(1) modelling fish growth and population dynamics

(2) species distributions and

(3) multi-species interactions and ecosystem dynamics.

At least 10 STSMs.”

16:00-16:15 Coffee break

16:15- 18:00 Afternoon session (synthesis and “homework”)

20.30 Dinner " Peschiera Pontis" Cabras.

Draft Manuscript

Conservation Physiology of Marine Fishes: Advancing the predictive capacity of models

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Abstract

At the end of May, seventeen scientists involved in a European Cost Action on Conservation Physiology met in Oristano, Sardinia, to discuss how physiology can be better used in modelling tools that can aid in the management of marine ecosystems. Current approaches to incorporating physiology range from models including none to others bursting with detail, and that consider everything from a single fish to global resources. Can we rise to the challenge of projecting future changes in distribution and productivity, assessing risks for local populations, or predicting and mitigating the spread of invasive species?

Introduction

The marine environment is changing at an unprecedented rate due to climate warming, acidification, fishing, eutrophication, hypoxia, and pollutants [1,2]. In the most recent decades, fish and other marine animals have generally responded to these changes by exhibiting poleward shifts in distribution [3], and evidence for changes in predator-prey relationships that affect ecosystem dynamics is mounting [4]. From a physiologist's standpoint, individual fish are affected by changing environments, but environmental managers, politicians, and stakeholders care more about species, ecosystems, and the humans that depend upon them. Connecting such vastly different perspectives requires tools that properly scale individual-level responses to population-level consequences and that can harness physiological principles to gain a cause-and-effect understanding of the effects of environmental change on fishes [5,6,7]. Our strategy for advancing the predictive capacity of models was to put physiologists, ecologists, experimentalists, and nerdy modellers into the same room, provide good food and Italian coffee, and hopefully unite around our common concern for conserving life on earth so that our grandchildren (and their grandchildren) can also enjoy it.

The main objective of the EU cost action on Conservation Physiology is to coordinate European research efforts on the physiological mechanisms that determine distribution and abundance of marine fish, including invasive species, and thereby contribute to sustainable management of biodiversity and fishery resources. A wide range of models and topics were discussed, spanning various levels of biological complexity (cell, tissue, organism, population) allowing broad discussions of aspects of fish physiology that could be integrated into different types of models. In the following, we provide a brief summary of these discussions and, for illustration, we structure this report around the effects of warming on species distributions.

Global bioclimate models with temperature envelopes

Whether warming will have an impact on species distributions and productivity clearly depends not only on the severity of local changes but also on the sensitivity of local species. Cheung et al. [8] quantified the thermal niches of some 600 species by overlaying observed distributions with current temperature maps. These niches were then projected onto outputs from global climate change models and used to predict spatial shifts. Clearly, observed species distributions contain more information than just tolerance limits and presence/absence. With a simple conceptual model of how temperature affects performance, it is furthermore possible to extract simple metrics for productivity in relation to temperature and thus project changes in abundance and biomass with implications for fisheries [9].

Resolving temporal and spatial scales

To be computationally feasible, global models rely on coarse spatial grids and sometimes annual timesteps. When projecting changes within a regional sea or a single ecosystem, temporal and spatial resolution of models can (and should) be much finer. Shorter model time steps (hours to minutes) and finer spatial resolution allow mesoscale (2 to 200 km) hydrographic features such as tides, fronts, and eddies that are important to biological processes to be represented. These temporal and spatial scales also match better with individual-level processes where physiology can translate local environmental factors into performance metrics such as growth and survival. These models demand more detailed physiological knowledge, such as species-specific rates of respiration, consumption, and digestion [10, 11]. Such detailed information can be directly useful to managers by, for example, mapping physiological metrics such as aerobic scope and how it changes on daily and seasonal timescales, across local geographical scales, or between different, adjacent habitats [12].

These smaller-scale models need to deal with increasingly complex aspects of physiology such as the cues for movement of fish life stages (from larvae to adults). Larvae have limited movement abilities, and particle tracking modules are often used to find their three-dimensional trajectory of environmental exposure which determines their growth and survival [13]. A particular strength of such strong coupling with oceanography models is that hindcasts can be compared to reveal causal relationships, and how physiology interactions with environmental features to affect year-class (recruitment) success [13]. During early life, the vertical swimming behaviour of larvae is not random but potentially tailored to a specific light level, food abundance, or individual state such as size or satiation [14]. In larger organisms, the capability of both horizontal and vertical movements is so great that it can no longer be ignored. By translating local environmental gradients into gradients of physiological performance, simple movement rules using only local information can be devised, and their consequences for species distributions compared with observations [15]. Differences in behavioural strategy expose individuals to different environments, which has consequences for growth and survival and serves as a mechanistic basis for individual variation within populations. Using evolutionary algorithms, it is furthermore possible to evolve movement strategies as adaptations to oceanographic and environmental features, taking the whole life cycle into account [16].

For models at this regional or ecosystem level, fisheries institutions routinely collect monitoring data on species distributions and abundance, age- and size composition and trophic interactions. All of this information, plus fishermen's knowledge [17], can be used either to directly parameterize physiological functions or can indirectly provide estimates of unknown physiological parameters [18].

Behaviour ecology connects environment and performance

Although regional, bio-physically coupled models have higher temporal and spatial resolution than global models, simplifications are needed to represent how individuals responding to local environmental changes. Behaviours can take place over short time windows each day, depend on rare events such as predation attempts [19], and can be flexible with respect to individual state [14]. The relationships between environmental variables and species responses can emerge within physiologically-based behavioural models. As an example, models including prey and predators environments may cause higher risk taking behaviours yielding insights regarding optimal foraging ecology [20,21] leading to tradeoffs where changes in food availability not only affect growth but can affect also the overlap with predators and therefore individual survival.

Recent developments of new sensors and data storage tags are likely to reveal exciting insights of highly detailed individual behaviour, also in wild fish [22], that can be included within models. Accelerometers can measure tailbeats that can be linked to metabolic rates, magnetic sensors applied to the jaws can detect foraging episodes, pressure sensors record vertical behaviour, etc. The potential for coupling temporally resolved behavioural and physiological data is particularly promising.

The adapted organism

An important question facing scientists dealing with environmental change is: Will species be able to adapt to these new environments or go locally extinct? At the most fundamental level, the whole organism has adapted and one can ask how multiple organ systems have evolved given their costs and functions. Although growth is commonly used as a proxy for fitness, growth is only one process competing for the limited resources available to an organism [23]. Thus, many of the properties experimental physiologists quantify in controlled laboratory experiments are caused by more fundamental, physiological and cellular processes that have evolved within specific environmental and ecological contexts. Examples of questions one can ask are what causes scaling relationships [24,25], and how do metabolic differences relate to diet specialization [26].

A hierarchy of models

The above has shown how models can be arranged in a hierarchy ranging from general insights from global models to specific projections for individuals in a specific area, and how new physiological knowledge may be infused at every level to refine the detail of model predictions. On the other hand, more detailed models can be used to help test implicit assumptions of more general models. Scaling from smaller to larger spatial scales may also be possible by coupling models. For example, coupling estimates of larval survival from local, risk-based foraging models into coupled bio-physical models of drift which, in turn, can be implemented as recruitment inputs within global models of fish productivity. In this way, physiological-based mechanistic effects within individuals can be systematically scaled to consequences at the population level, while being consistent about the role of behaviour. With this view in mind, the value of incorporating physiology into models should always be assessed relative to models that lack physiology (the null model). For example, Burrows et al. [27] mapped the expected change in surface temperature divided by the local temperature gradient, providing a metric of the horizontal velocity a species would need to move to stay within the same thermal niche.

Meeting outcomes

Central outcomes from the meeting included three realizations. First, modellers should acquaint themselves with the details of other types of models (including null models) to understand how specific (complex) models might be compared or coupled to more general (simple) models to test and refine tools. Second, physiologists should think deeply about the level at which their knowledge can be best applied (e.g., accepting greater approximation in more general models) and acknowledging that measured quantities reflect adaptations influenced by a species ecology, behaviour, and phylogeny. Finally, cross-disciplinary discussion are challenging but very rewarding. They might be painful at first due to differences in vocabulary and jargon, or a misalignment of concepts due to disparate backgrounds (cellular biochemistry, environmental physics, or evolutionary adaptation), but through these discussions one's invested beliefs may falter, leading a broader canvas being painted, together. This was a rewarding experience for us, our first step towards building better models for conservation physiology of marine fishes, and one that other, interdisciplinary groups will share.

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