ICES International Council for the Exploration of the Sea
CIEM Conseil International pour l'Exploration de la Mer

Theme Session J – Environmental Sustainability of Aquaculture Activities in Coastal Zones

Conveners: Karin K. Boxaspen (Norway), Ingrid Burgetz (Canada), and Einar Dahl (Norway)

Aquaculture has become increasingly important for the production of marine food and feed stock, and at present and for the near future, most aquaculture production is likely to take place in coastal zones. This causes increased pressure on the coastal zone and space and resource competition among different uses or industries. In addition aquaculture activities may have various direct and indirect effects on the coastal zone ecosystem. Potential influences from aquaculture may include discharge of nutrients, sedimentation of organic material (i.e., pellets and faeces), dispersion of chemicals (i.e., therapeutants and impurities), spreading of "signal" substances or concentration of pathogens. This may lead to eutrophication – potentially resulting in enhanced productivity or a shift in biodiversity. Wild species may be attracted to or displaced from aquaculture sites and may feed on pellets and/or faeces and potentially resulting in effects on wild species health status. Aquacultured species may also be a source for spreading of pathogens to wild organisms, as well as being susceptible to pathogens from wild species. Should all these potential effects be realized in a coastal ecosystem, there is a potential for the aquaculture activity to be unsustainable and result in coastal ecosystem degradation. However, with scientific research, technological advances and knowledge, the potential negative effects from aquaculture should be possible to avoid through good planning and management of aquaculture activities as well as the implementation of efforts to minimize or mitigate any potential negative effects.

This Theme Session is well aligned with the second thematic area of the ICES Science Plan: ***Understanding Interactions of Human Activities with Ecosystems*** - *Carrying capacity and ecosystem interactions associated with mariculture,* and touched on *Marine spatial planning* as well. The Session was comprised of 12 oral 3 poster presentations largely divided along four thematic areas: (1) Sustainability of aquaculture activities; (2) Carrying capacity for different types of aquaculture; (3) Disease transmission in coastal areas; and (4) Effects of aquaculture on biological assets in the coastal zone.

Sustainability of Aquaculture Activities

Throughout all of the presentations the overall theme of sustainability of aquaculture activities was presented. However, a few presentations were more specifically focused on sustainability or related equally to multiple session themes, specifically carrying capacity and effects on biological assets, this overarching but specific and unanticipated sub-theme arose during the session.

In a number of presentations the need for including different stakeholder groups at the early stage of research and research planning was highlighted. The concepts of marine spatial planning and integrated coastal zone management, as well as the importance of communicating results and consulting with different marine service users were highlighted in case studies from Tasmania, Australia (J:07), to Thau Lagoon, France (J:05) to Rhode Island, USA (J:03).

In Tasmania, collaborative projects involving researchers, government regulators and the aquaculture industry to predict overall carrying capacity of the region where aquaculture is occurring was presented. The resulting models from the research were designed to predict the footprint of aquaculture activities on a farm-based scale, and focused on knowing how to influence fallowing in order to maximize production. From this successful initial study and model, a second phase was initiated on a system-wide scale in order to examine broader ecosystem effects. The Aquafin model was used to evaluate different production-based scenarios, which led the industry to agree on an overall system production cap. Additionally, the model has been used to design cost effective monitoring programs to validate and adjust the model over time. Building on the success of these projects, there is currently research to develop a new integrated model and observation network that includes multiple marine services users, including the aquaculture industry, in order to develop more realistic assessments for calculating carrying capacity that reflects the multiple users of the system, and thereby helps to ensure the sustainability of operations.

Sustainability of shellfish aquaculture operations in Thau Lagoon, France was presented specifically related to the impacts from other anthropogenic inputs into the environment (i.e., E. coli). Marine spatial planning approaches and socio-economic considerations were examined as part of the larger SPICOSA project. Sustainability aspects related to production bottlenecks were presented for pearl aquaculture (J:14) and compensatory growth following starvation in cod (J:18, poster presentation).

Environmental sustainability related to the collection of mussel seed in the Netherlands was presented, as the change from dredging for seed to using seed collectors has had the dual effect of increasing overall biomass through the addition of habitat (see collectors) and retention of seed in the wild beds, thus potentially impacting the overall carrying capacity of the system. In addition, the organic deposition associated with the spat collectors was modeled, both with and without current; the prediction that there would not be an accumulation of organic deposition beneath the spat collectors in areas with currents was validated through sampling.

Carrying Capacity for Different Types of Aquaculture

In addition to the carrying capacity estimates for mussel aquaculture in the Netherlands due to a shift in spat collection practices, the aquaculture carrying capacity research presented used different models (e.g., Ecopath, current-derived model, and DEPOMOD) to predict organic enrichment and associated carrying capacity implications.

Ecopath was used in order to predict the carrying capacity of lagoons in Rhode Island, USA, in order to support sustainable oyster aquaculture growth. The model was populated with data associated with different marine ecosystem services and then scenarios with different oyster culture production were run in order to predict the overall carrying capacity of the lagoons.

On a farm-based scale, biodeposition associated with mussel culture was presented for predicting and validating models of farm footprints using current-derived models for two different farms in a Faroese fjord. The current-derived model was dependent on the seabottom current speed, with faster currents resulting in a decreased predictive capacity of the model which is likely linked to the resuspension of wastes. However, at slower seabottom currents (<10 cm s^{-1}) the model accurately predicted biodeposition. The recovery rate that was observed following the cessation of farm-

ing activity was notable after a month through improved benthic conditions, however the carbon removal that occurred could not be explained by carbon flux alone.

Using benthic community response to organic biodeposition by mussel culture at different densities was presented. Using mesocosms and different mussel densities, the overall benthic community structure was examined over a period of time. At 200 to 400 mussels m^{-1} there appears to be a tipping point where the benthic community undergoes a dramatic shift in structure associated with the organic biodeposition from the cultured mussels.

Disease Transmission in Coastal Areas

This theme area had originally had two presentations scheduled, but due to a late cancellation, there was only one presentation which focused on viral haemorrhagic septicemia (VHS) in Norway. Norway experienced the first outbreak of VHS (genotype III) in farmed rainbow trout between 2007–2009, resulting in chronic presentation of the disease with low but steady mortality. Genotype III of the VHS virus is pathogenic to cod larvae, and this was the first isolation from rainbow trout of this genotype. Despite sampling wild stocks for the presence of VHS genotype III, only one fish has been found with the virus, although this very low prevalence may be linked to not sampling herring or in coastal waters where farmed and wild fish interactions can occur. The current research discussed highlighted the need to do further assessments, including disease challenges on herring in order to try and determine susceptibility.

Effects of Aquaculture on Biological Assets in the Coastal Zone

Within this theme the presentations varied in examining the effect of noise on protected species, genetic interactions, and the effectiveness of replacing fishmeal and fishoil in aquaculture feeds in order to decrease the pressure on wild fisheries.

In order to minimize the interactions between wild seal populations and caged salmon in Scotland, 50% of the fish farms employ acoustic deterrence devices (ADD). However, within the vicinity of the farms a marine protected species, the harbour porpoise, is found. Studies have not been executed to determine the effectiveness of ADDs on deterring seal attacks, farmers continue to use these devices over anti-predator nets. The study presented examined the presence of harbour porpoises during and after ADD deployment in order to determine whether the ADDs disturb the porpoises, which would be in contravention of the marine protected species legislation. Harbour porpoises appear to acclimate to the presence of ADDs, after an initial period of avoiding the areas where new ADDs are deployed while the devices are turned on.

Two presentations focused on genetic interactions between farmed and wild Atlantic cod, one evaluating a possible mechanism to mitigate genetic interactions through determining the viability and rate of deformities in inbred cod embryos, and the other examining the population of cod in the immediate vicinity of cod farms in Norway (presented as a poster, J:17). In eastern Canada cod farming is a fledging industry. Of concern is the possibility of genetic interactions with wild populations. The study compared the viability and relative deformities of embryos from inbred and unrelated crosses in order to determine whether using siblings in an enclosure would mitigate the possibility of genetic interactions with wild populations. Although no significant difference was found in the number of deformed embryos at hatch, the unrelated crossed embryos percent hatch rate was significantly higher. Further studies are planned to further determine viability of sibling crosses.

Conclusion

Ecosystem interactions associated with marine aquaculture, including considerations regarding carrying capacity, wild-farmed fish disease interactions and moving to integrating aquaculture as a marine service into multi-user integrated models for marine spatial planning is clearly of interest to countries in the North Atlantic. This session provided an opportunity to highlight some key areas of research that have relevancy to the ICES Science Plan and aligns with the work by various ICES expert groups and the strategic initiative on marine spatial planning. As ICES continues working in the area of carrying capacity and ecosystem interactions of mariculture, future theme sessions during the Annual Science Conference should be considered as this session provided a focal point for a number of similar challenges and opportunities related to marine aquaculture interactions to be presented. Future theme sessions, while aligning with ICES mariculture-related expert groups' workplans, could build on the sub-themes explored during this session and that are highlighted in the ICES Science Plan, particularly as they relate to disease management and the contaminants associated with disease control and feeds, escapement impacts and mitigation of aquaculture-environment interactions.