Clyde 2020 – Research Advisory Group advice to the Clyde 2020 Steering Group

08.06.2016

Background

Following the Clyde 2020 summit in 2014, the subsequent workshops and publication of the 'Action Plan', the Clyde 2020 Steering Group felt it would like more advice about the priorities and rationale behind any projects that would be conceived under the Clyde 2020 Vision.

The Research Advisory Group was subsequently opened for applications from individuals and senior scientific advisors recommended a series of appointments. The RAG met face to face in early February 2016 and shared information in the form of presentations and discussion. They then went away to consider priorities for research and practical projects.

The following are recommendations from the RAG to which the Steering Group should give due consideration. ***The SG is at liberty to decline or add to the advice and propose alternative or additional priorities.*** The RAG is keen to note that they wish to adopt the precautionary principle to all issues raised or researched. They also wish to be as open and transparent as possible in order to help instil confidence in outputs which are aimed to serve the communities and marine environment of the Clyde.

Research Advisory Group Discussion Summary

The Clyde 2020 programme is about the enhancement of the ecosystem for the benefit of all. At this time there is an assumption that spatial management of the Clyde will have measurable benefits on ecological health. Existing spatial measures are for specific purposes e.g. the MPA's are there for the protection of specific features for example the no-take-zone for ecological enhancement and research and the cod box, which recent research seems to indicate has been ineffective, is there to protect spawning grounds. This makes existing spatial measures hard, but not impossible, to use as test beds for any new management measures under the Clyde 2020 banner.

There is often a correlation between a closed area and resulting benefits to fish stocks. Whilst this may be the case at times it is not always guaranteed; some benefits are relatively minor and difficult to assess and attribute e.g. the sand eel box off the west of Scotland was beneficial for sand eels but not demonstrably beneficial to fish stocks. Questions arising from this are;

- What are the objectives of the current (and any proposed) spatial management measures? Protection of features, increased biodiversity, fisheries benefits?
- What are the best methods/research projects to assess the success of management measures relative to their objectives?
- Do the spatial management measures complement each other and provide additional benefit specifically to the Clyde area (as opposed to smaller units or larger areas)?
- How can research inform selection of spatial management measures to best meet their objectives and optimise benefits?

This is a simplistic assessment of a complex picture. However we must bear in mind the altered ecosystem, as evidenced in the Clyde Ecosystem Review, and the consequent need for steps to be taken to encourage the improvements in species diversity and density to the benefit of all.

RAG Clyde 2020 Conclusions

- The overarching conclusion of the RAG is that there is ***no single priority action***, project or research proposal which can be identified that will achieve the Clyde 2020 vision.
- A ***strategic view is needed*** which looks at all the options now available to manage the Clyde marine region including the role of spatial management, pollution, disease, human induced pressures and so on.
  NB This is largely the role for the newly established Clyde Marine Planning Partnership as it starts on its work to create a Clyde Regional Marine Plan over the next few years. RAG believes its collective range of scientific expertise has much to contribute to this process.
- A prerequisite for this work is the need for a holistic ***assessment of the stock*** in the Clyde. This should include as many commercial and non-commercial species as is possible and relevant.
- Addressing the questions asked above requires ***capacity*** to work intensively with key stakeholders, in particular with fisheries and conservation interests, to increase confidence, enhance understanding and share priorities.

Research Priorities

The Research Advisory Group undertook an analysis of research priorities based on the 'Clyde 2020 Action Plan' produced by the workshops held in 2015. Working under the proposition that spatial management of the Firth of Clyde will have measurable beneficial effects on the ecological health and environmental status of the Firth as a whole and that by 'ecological health' we mean properties of the ecosystem which may be measured by various relevant indicators, including those used by the Scottish National Marine Plan, which are applicable to sub-regional ecosystems such as in the Clyde. These include, but are not limited to, a Large Fish Indicator (LFI) of >=0.3 and a species evenness of >=0.5 (current LFI <0.1, current evenness ~0.2). With this in mind the following is a list of the research projects which the RAG felt would be of most benefit.

Please note that these priorities are not listed in any particular order and are presented at an early draft/discussion stage – text relating to each item should therefore be considered indicative rather than comprehensive.

Title	**Status**
Modelling the fishing activity patterns required to meet ecosystem service goals in the Firth of Clyde	MASTS PhD programme funded by SNH
Description The goal of the project is to configure and adapt a whole-ecosystem simulation model to represent the Firth of Clyde, and use it to investigate the response of the ecosystem to fishing by the range of different gears in use. Using the model, the project will then be able to advise on the distributions and intensities of activity by different gears which may be required to achieve various objectives defined in terms of ecosystem services.	

The research is expected to make a substantial contribution to the Clyde 2020 process. The Clyde Summit and subsequent workshops all identified an ecosystem model capable of simulating the ecosystem service outcomes of alternative strategies for managing fishing activity in the Clyde, as a key research requirement.

Concept Contributors / Concept lead (for active/funded projects) : PhD supervisors Prof Heath and Dr Bailey

Title	Status
Can spatial management of marine activities improve measures of sea-floor integrity (structure, ecosystem functions, diversity) compared to open access for activities such as mobile gear fishing?	Unfunded

Description/Discussion

Examination of the benefits of the multiple closed areas which make up a network. This may have additional ecosystem benefits and would be a model for larger MPA/MPZ networks.

There are a number of closed areas in the Clyde - look to encourage projects which look at the benefit of these as a group as well as individually.

Investigate the possibility of using technology to monitor activity, with separation of static and mobile gear, so data can be collected over time.

A key element of this project would be to monitor recovery rates in different protected habitats and in areas subject to different past levels of pressure. How does ecosystem function and the delivery of ecosystem services (e.g. nursery habitat function for different species, water filtration) vary over time in these different areas? What are the costs / benefits of this approach for fisheries relative to other forms of management?

Outputs could look to provide recommendations on approaches for spatial management in the Clyde which could optimise the ecosystem benefits of closed areas while minimising the impact on industry. This could include projects which encourage stakeholder engagement.

Concept Contributors / Concept lead (for active/funded projects): Dr Mouat, Dr Campbell, Dr Beukers-Stewart

Title	Status
Are fish numbers, growth rates and survival correlated with measures of seafloor integrity or are other factors at play?	Unfunded

Description/Discussion

In relation to this hypothesis, recent research results have shown:

- Juvenile demersal cod prefer undisturbed complex habitats as this promotes their growth and survival.
    - PhD research at Glasgow University has shown that juvenile cod around south Arran are significantly more abundant on pebble/gravel and heterogeneous seabed

substrates than on homogeneous and muddy substrates (Elliot 2016). It is suggested that these more varied regions of seabed provide more opportunities for camouflage and refuge.

- Juvenile haddock and whiting prefer other (muddy) habitats.
    - The PhD research around south Arran (Elliot 2016) showed that whilst juvenile cod are more abundant on complex substrates, juvenile haddock and whiting are not. These species are more abundant over homogeneous muddy sediments.
- Growth rates of haddock and whiting (PhD research at Strathclyde University, Hunter 2016) have declined in the Clyde so that, for example, 4-year old fish are now around 5cm smaller than they were in the 1980's. This is part of a widespread pattern throughout the west of Scotland, but has been most rapid in the Clyde.
- The same is not true for cod, which have shown little or no change in size-at-age over the same period.
- The changes in growth show no relationship to temperature or to stock abundance so it is concluded that they are not due to warming or any density dependent effects (competition for food).

The following questions remain to be tested:

- Do the large fish captured in the recent commercial vessel surveys belong to the same population as is sampled in the routine surveys?
- Trends in declining fish size-at-age and length-at-maturation (haddock and whiting) are not reversible in meaningful time scales, and mean that even if survival is increased by protecting juvenile habitat the effect on the LFI will be minimal. In any case, how would we reverse the declining size at age?
- Changes in plankton productivity of the Clyde cannot be ruled out, though this would not explain the wider-scale phenomenon throughout the west of Scotland. Trawling intensity (hours fished per km2) is the only factor which correlates spatially and temporally with the changes in growth rate of haddock and whiting. If the changes in growth are partially due to fishing induced evolution then it may take many generations for the changes to reverse. However, it remains a mystery as to why cod growth should not be similarly affected.
- Would effects of warming temperature on survival and growth of fish overwhelm any survival benefit of protecting complex habitats? Additional food web impacts through warming effects of zooplankton and benthos are unknown.
- Would effects of changing river catchment nutrient discharge on primary productivity, through zooplankton to fish survival and growth, overwhelm any survival benefit of protecting complex habitats?
- Could fish immigration and emigration effects dominate over local survival effects?
- Would displacing fishing effort from complex habitats without removing it from the region as whole have no effect on survival?
- Would large/old fish benefit from protection measures enough to recover size frequencies?

Other factors

- North Ayrshire Council (APPLICATION 16/00117/PP - ARRAN DISTILLERY SEA OUTFALL) has just granted planning permission for Arran Distillery to discharge untreated high organic content (high COD) waste through a sea outfall, into the waters of the Kilbrannan Sound. The principle of using dilution and dispersion to dispose of contamination was removed in the 1980's when it was realised that utilization of the surrounding environment's assimilation capacity was invariably accompanied by a detrimental cost. The distillery is about to incorporate an additional two stills, and with a new distillery on the south of the island also expected. The alternative of effective treatment (anaerobic digestion) within the industrial site is well established technology and practice in the Scottish whisky distilling

industry as recorded in the Scottish Whisky Association's environmental strategy publications. All new distillery investments would be expected to treat their effluent on site. Indeed there is an example of a new distillery adjacent to the Dornoch Firth which is so equipped.

- North Ayrshire Council (Application16/00467/PPM) A new distillery on SW coast, inside MPA which includes suggestion of a further 2 tanker loads of waste per day. Presumably to be sent down above Distillery Sea Outfall?
- There is an ambition to increase capacity and open new mariculture facilities potentially resulting in changes in nutrient levels in the sea lochs, plus addition of pharmaceuticals to control lice and disease.
- Should Clyde 2020 be attempting to monitor such events in the Clyde? As a relatively enclosed system, all discharges are having effects.

Concept Contributors / Concept lead (for active/funded projects): Prof Heath, Dr Campbell

Title	Status
How has the mortality rate on white fish, due to by-catch changed over time? How do we manage mortality in a scenario where fish stocks recovering.	Unfunded

Description/Discussion

By-catch rates of demersal fish in the Nephrops fishery are reported to be low (I.e. numbers of fish caught per tonne of Nephrops), but what contribution does this by-catch make to the mortality rate of the small demersal populations in the Clyde? And does the removal of larger fish in the by-catch restrict fish stock recovery?

Getting accurate data on by-catch is an essential part of an accurate stock assessment. It is widely reported by the fishing industry that by-catch in Clyde Nephrops trawl fisheries is now very low. This contrasts with an earlier analysis conducted by Bergmann et al (2002) which reported very high rates of bycatch (~80% by volume). This project would combine a contemporary by-catch survey with mining data from past on-board observations of bycatch. Key questions to address are:

- How have by-catch rates changed?
- How does by-catch vary in different gear types / areas / seasons?
- Have changes in gear selectivity changed by-catch rates?
- How do by-catch rates vary in relation to temporal and spatial variation in the abundance of fish and invertebrate species on fishing grounds?

This project would need to involve strong collaboration with the fishing industry – which may make it eligible for funding recently made available by the Scottish government to hire commercial vessels for scientific research

Concept Contributors / Concept lead (for active/funded projects): Dr Bailey, Dr Beukers-Stewart

Title	Status
Fish behaviour differs between closed and open areas, through learning. There are therefore changes to carrying capacity and selection of fish with smaller home ranges	Unfunded

within closed areas?	

Description/Discussion

This hypothesis raises the following questions:

- Are complex habitats in the Clyde area a rich source of food for demersal fish?
    - Data on the species composition and abundance of benthos in relation to seabed substrate types and heterogeneity are currently lacking, so we cannot address this issue at the moment.
- Is a significant proportion of the juvenile Clyde fish population currently located in trawled complex habitat?
    - We do not have detailed enough seabed substrate maps of the Clyde and sea lochs to enable us to estimate what proportion of the region is composed on habitat which, around south Arran, supported high abundances of juvenile cod. However, it would be possible to estimate this from the modelling method described by Elliot (2016). This involved predicting seabed substrate from current speeds calculated by a high resolution hydrodynamic model (Sabatino 2016), wave fetch and seabed depth.
    - The predictions could then be validated by a relatively modest seabed survey including sampling of juvenile cod. As to whether the complex habitat which supports juvenile cod is currently trawled, we would need to compare the predicted substrate map with VMS data for different fishing gears. We would expect that the Nephrops trawl fleet does not impact the complex habitat and instead is concentrated in the homogeneous muddy sediments. However, the same may not be true for the scallop dredge fleet.
- Will a closure significantly reduce mortality of the protected fish, or are we protecting habitats with generally low fishing pressure
    - This can be checked through analysis of fisheries data (VMS)?
- Is there evidence of a survival benefit from complex habitats remaining undisturbed?
    - We are not aware of any evidence to support or refute this.
- Is there a significant proportion of the juvenile fish population in complex habitat that is not currently trawled?
    - Data to support or refute this are not currently available – see comments above relating to seabed substrate prediction and mapping onto VMS data.

Concept Contributors / Concept lead (for active/funded projects): Prof Heath, Dr Bailey, Dr Beukers-Stewart

Title	Status
Detailed mapping of habitats/seabed as well as fish distribution is needed in the Clyde.	Unfunded

Description

Detailed mapping of habitats/seabed as well as fish distribution in the Clyde is needed. Output from the high resolution hydrodynamic model of the Firth of Clyde developed at Strathclyde was used alongside field sampling data by Sophie Elliot (Glasgow Univ PhD) to generate a detailed habitat map for South Arran. This work could be extended to other areas of the Clyde relatively easily, providing maps of the landscape across wide areas of the region.

Historic surveys from the 1980's give some information on fish distribution of the whole area but this has not been repeated. This needs to cover all species and all sizes (i.e. not just landable size).

Concept Contributors / Concept lead (for active/funded projects): Prof Heath, Dr Bailey

Title	Status
Changes in community structure and function in closed areas affect the transfer and re-suspension of soluble and insoluble pollutants (e.g. microplastics).	Unfunded

Description/Discussion

There are numerous documented inputs of both organic and inorganic contamination into the Firth of Clyde including sources as diverse as agriculture, industry (including distilleries mentioned above), effluent (municipal and industrial at various levels of treatment), shipping, municipal run off and the re-suspension of historical pollutants in sediments including heavy metals (Pb, Cr, Hg) and persistent organic compounds (e.g., dichlorodiphenyltrichloroethane, polychlorinated biphenyls, hexachlorocyclohexane). Sources are not only from around the Firth itself but also as a result of the freshwater influences (e.g. river Clyde) feeding into the Firth.

With the potential for development in several sectors (aquaculture, fisheries, coastal development, energy, ports and shipping, recreation and tourism) within the Firth there is the potential for further increased pollution to impact on the ecology (water, sediment and biota) of the area.

There is increasing evidence to suggest that the presence of microplastics has ecologically relevant impacts and can affect reproduction in economically important aquaculture species (e.g. oysters; Sussarellu et al., 2016. PNAS Vol 113, No 9 pp 2430-2435). Not only can microplastics cause an ecologically relevant impact but they can also interact with existing chemical contaminants acting as a vector for exposure further increasing bioavailablity.

As numerous contaminants have been found in the Firth of Clyde along with microplastics in the water, sediment and biota (particularly Nephrops (Murray & Cowie, 2011, Marine Pollution Bulletin, 62(6) 1207-1217)), the combination of these two has the potential to impact not only the ecological health of the region but also on the economic impact on both fisheries (fish and Nephrops) and any future potential aquaculture developments.

- A holistic study to investigate (or collate existing data) the levels of microplastics in the water, sediment and biota in the region along with the chemical analysis of these pollutant to investigate their potential concentrations and bioavailablity and their potential impact on community structure.
- This could be developed as a citizen science project, perhaps utilising community groups, schools or FSC, accumulating data from regular seasearch, nurdle hunts, bottle counts.

Concept Contributors / Concept lead (for active/funded projects): Dr Quinn

Title	Status
Changes in population density and size frequency within closed areas affect disease prevalence, transmission rates and intensity (e.g. of Hematodinium).	MASTS PhD programme funded by MSS

Description

PhD student (Hazel Smith) at Strathclyde University, jointly supervised by Doug Speirs (Strathclyde), Douclas Neil (Glasgow) and Mike Heath (Strathclyde), is developing a population dynamic model of the Nephrops – Hermatodinium host-parasite interaction. Questions being addressed include:

- Will a change in age/size structure affect degree of prevalence?

- There is evidence that for example smaller/medium nephrops had a higher prevalence of Hematodinium (Stentiford et al, 2001; Field etal 1998). Disease expression found to be related to moulting. As the proportion of susceptible hosts increases in the population disease can spread (Stentiford and Neill, 2011).
- Change in behaviour through disease affects spread affects mortality (Field, 1998; Stentiford et al 2015).
- Change in density could affect the transmission rate.
- Plankton productivity changes in different localities of the Clyde during spring bloom related to Hematodinium rates of infection.
- Role of infection in capture sensitivity.
- Role of discarded animals in sustaining the parasite population.

Individual based models of disease transmission can enlighten the predictions with changing population density and size frequency. Other methods: spatial and population dynamics modelling; density-dependent vs. frequency dependent transmission (is there a density-dependent contact rate?).

Concept Contributors / Concept lead (for active/funded projects):Prof Heath, Dr Miethe, Dr Mouat, Dr Campbell

Title	**Status**
Spatial protection measures lead to changes in population density and size frequency of harvested animals (Nephrops, Pecten, fish) across the wider area.	Unfunded

Description

- Can we expect a change in population density and size frequency from the protective measures?
  - Estimate reduction of mortality with protective measures (VMS, fisheries data); size-based population modelling to predict effect. Compare to actual effects from other areas with similar protection measures.
- Can the increase in population density deliver significant contribution to the wider stock?
  - Not expected if the protected area affects only a small proportion of the wider stock or mainly sedentary stocks.
- Do the migration patterns indicate an export of adult fish?
  - Tagging studies to determine fish migration patterns are desirable.
- If there is an contribution to the wider stock expected, can this be diminished in the future by individual behavioural changes in movement and migration patterns
- Are the dispersal dynamics promoting export of larvae
  - Oceanographic modelling of larvae dispersal, to determine wider contribution of recruits. This could be done using the model inputs of particle dispersal of the FVCOM hydrodynamic model by Sabatino (2016).
  - This can be important also for sedentary stocks

A considerable about of work on scallops has already been done in the Isle of Man. It may be the case that there are some benefits from closed areas for fisheries. It may be difficult to infer benefits to fisheries if areas have not been chosen or closed for fisheries enhancement/management reasons. Benefits may be slight or not apparent, but that does not mean that closed areas within the Clyde area cannot be beneficial to commercial stocks.

Concept Contributors / Concept lead (for active/funded projects): Dr Miethe, Dr Mouat, Dr

Beukers-Stewart

Title	Status
Hydrodynamic connectivity in the Firth of Clyde	Semi-funded
Description Completion of the hydrodynamic modelling PhD project at Strathclyde has produced a high resolution simulated dataset of 3-dimensional currents over a number of modelled years in the Clyde. Computer code has been developed and is being used to simulate the drift tracks of particles released anywhere in the Clyde region. Currently the scheme is being used to investigate the dispersal of Nephrops larvae, but can also be envisaged as being used to: • Track the dispersal of pollutants or spills. • Determine the dispersal of scallop and fish larvae and sea lice from salmon cages. • Determine the hydrodynamic connectivity between any network of proposed closed or protected areas.	
Concept Contributors / Concept lead (for active/funded projects): Prof Heath	