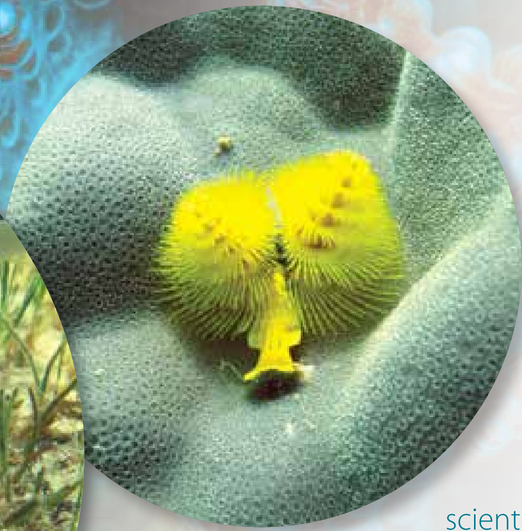
Understanding marine 'connectivity'



At first glance all the oceans of the world are connected as myriad organisms swim or drift in the same watery medium. In reality however marine waters move in a complex way caused by currents, winds and tides, and the distributions of marine plants and animals are much more complex. Parks and Wildlife marine scientists are carrying out a collaborative study focused on the Pilbara and with links to the wider WA coast, that will provide information to help understand how populations of marine organisms are isolated or connected, and what this means for managing our unique marine environment.

by Richard Evans

On a recent trip to Ningaloo, I came across a fisherman who had obviously seen the 'research' sign on my boat and asked "What ya researching?".

"I am doing a study to understand how all the different marine regions of the Pilbara are connected," I replied.

To which he quickly turned with a confused look on his face and bluntly said "They're all connected mate".

"Yes… and… no, at varying levels" I replied, thinking "I wish it was that easy". The fisherman's response had startled me in its simplicity, but he was right: all the oceans are connected to some extent. However, the complexities of oceanography mean that marine waters often do not mix as well as some might think and this affects how populations of animals or plants are genetically similar or different in what may look like entirely uniform coastal waters.

The presence or absence of such connectivity could help to explain how some marine taxa survive or recover from disturbances or environmental influences that occur over short or long time spans. This fisherman's comment prompted me to write this article to explain what scientists mean when they refer to 'connectivity'. While the *Merriam Webster Dictionary* definition of the word connectivity is "the quality, state, or capability of being connective or connected", connectivity from an ecological perspective means the relevant exchange of individuals which impacts the survival of a species in a local population.

INFLUENCING CONNECTIVITY

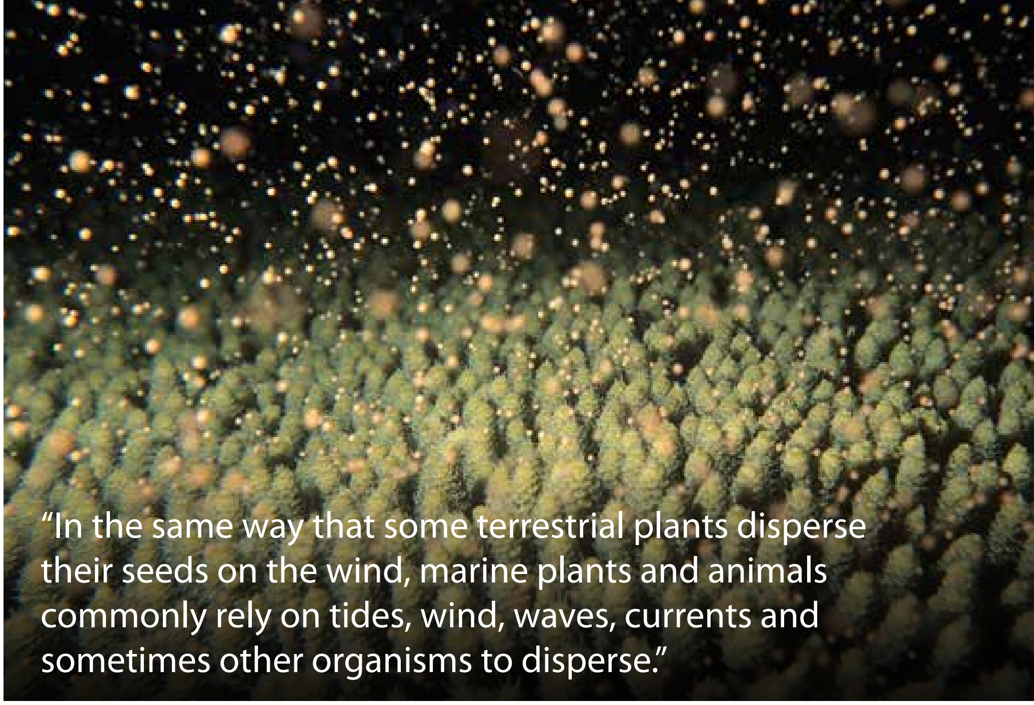
Marine organisms that live as adults on or near habitats like coral or rocky reefs, seagrass or macroalgal fields typically have a remarkably different early life. They spend their early life stages as tiny eggs and larvae floating or swimming as plankton in the currents of the open sea. Currents may either transport them to other reefs or keep them in the vicinity of reefs in the area in which they were born. After a period of time and as they grow, these larvae have the ability to settle from the water column into suitable habitats to begin their life on or near their habitat of choice. The average time spent in the water column, known as the 'pelagic larval duration', varies between species and can range from seven to 10 days for coral larvae and 10 to 80 days for larval fish. For many species, this pelagic larval stage is when they disperse widely. Dispersion may also occur as adults, however many species are either attached to the seabed or have relatively restricted home ranges or territories that may be only tens or hundreds of metres in size. Obviously this varies widely and some mobile fish have the ability to swim kilometres by the time they reach adulthood.

Until recent decades, scientists believed marine organisms existed in open populations, with the ability to disperse thousands of kilometres ("They're all connected mate!"). More recently however, research has shown that most marine organisms disperse over relatively smaller distances of up to about 15 kilometres in a single generation. Yet, if their inter-generational movement is so limited, why do many species exist across entire oceans?

Opposite page
Main Anemone fish.
Photo – Richard Evans/Parks and Wildlife
Inset Loggerhead turtle hatchling.
Photo – Jiri Lochman
Background Healthy hard coral from the family Faviidae.
Photo – Matt Kleczkowski

Above left Fish in seagrass.

Above Christmas tree worm.
Photos – Richard Evans/Parks and Wildlife



The answer lies in the benefit of time, with species using a series of generational stepping stones to cross large distances. In some instances, larvae can travel hundreds of kilometres in a single generational event under the influence of unusual conditions like cyclones or strong ocean warming events which can carry larvae well beyond their normal dispersive range.

Such an event occurred off the coast of Western Australia during 2010 when an exceptionally strong Leeuwin current transported hot tropical water all the way down past Perth, carrying with it the larvae of many tropical marine species. Unfortunately, many of these did not survive the onset of winter, or were not able to successfully breed if they did survive. Remarkably, marine scientists now believe that some vagrant species from tropical waters are now surviving in temperate waters as they are now slowly migrating south. But this is another story.

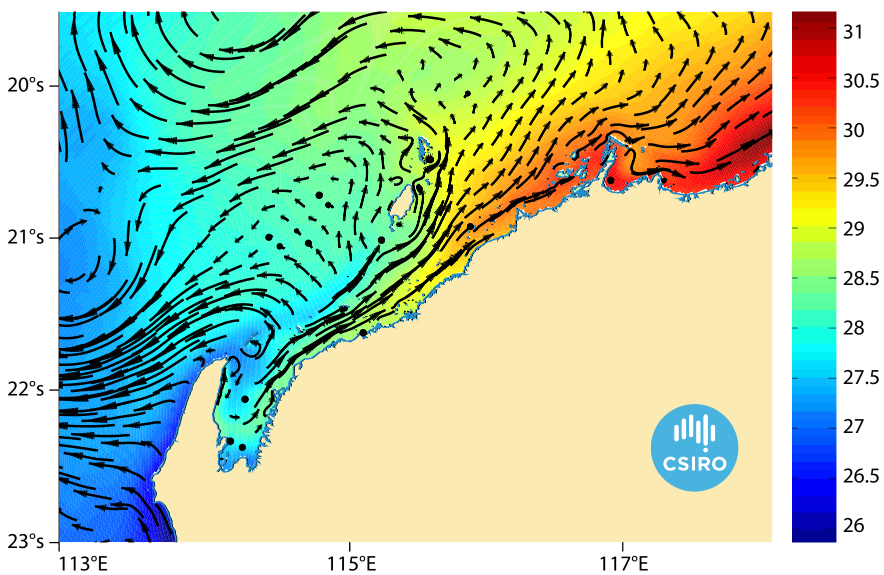
DIFFERENT DISPERSAL METHODS

The fluid nature of the marine environment enables organisms to disperse differently to terrestrial organisms. In the same way that some terrestrial plants disperse their seeds on the wind, marine plants and animals commonly rely on tides, wind, waves, currents and sometimes other organisms to disperse. Dugong, for example, disperse seagrass seeds in their faeces, often after travelling some distance from where they may have foraged.

The young of some organisms develop within their parents or on the substrate where their eggs were laid, which is known as 'direct development'. These organisms typically have limited dispersal from their parents. Sessile organisms (attached to the sea floor) may only disperse a matter of metres. While fish may hatch from eggs and disperse up to several kilometres through active swimming with local currents.

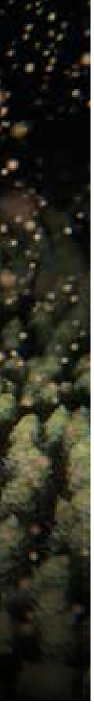
Plants or animals without the ability to control their horizontal or vertical movement – such as some species of seagrasses and mangroves – are referred to as 'passive' dispersers. Dispersal of these organisms relies solely on the environmental conditions to distribute their reproductive outputs (propagules). Some organisms may delay settlement to the benthic environment to enhance their chance of finding suitable habitats.

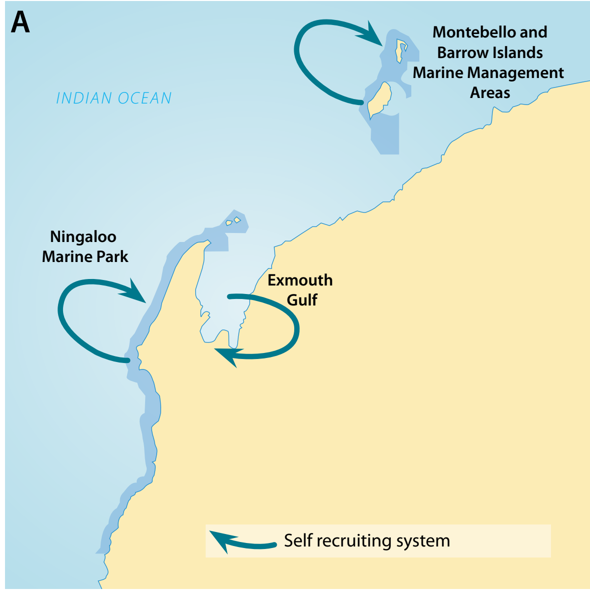
Animals such as corals can control their vertical position in the water column and are understood to have 'passive movement with vertical migration'. The water column does not always move as one body of water, at times there are eddies, and temperature and salinity variations which allow different sections of the water to move in different directions. Organisms with vertical migration mobility

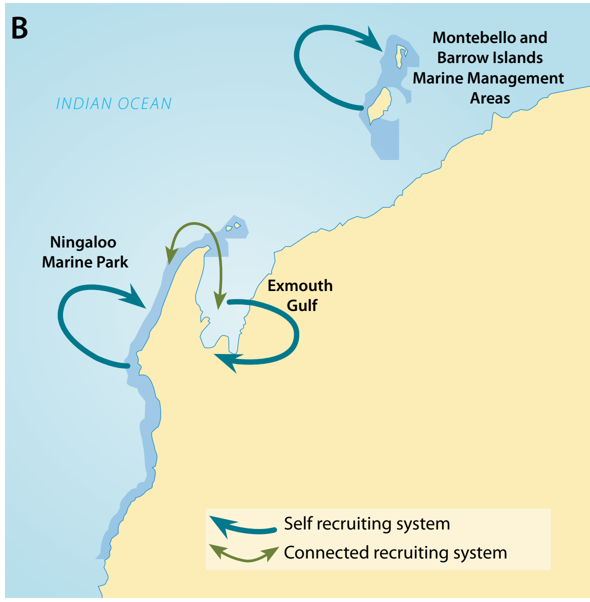


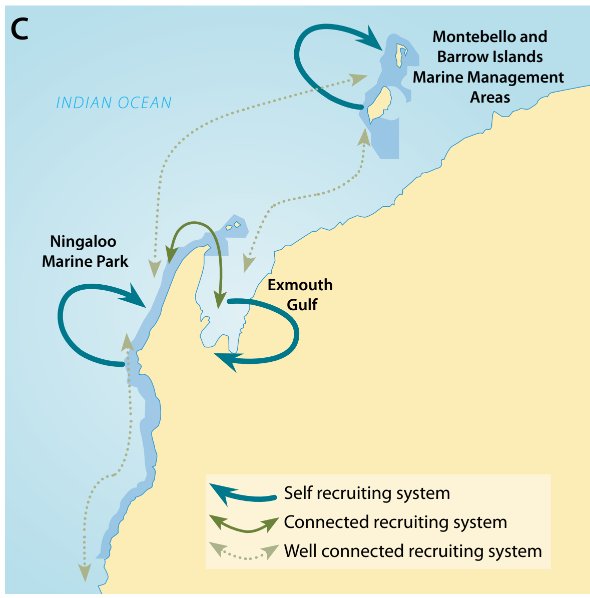
Above Coral spawning.
Photo – Geoff Taylor/Lochman Transparencies

Left A model of average water movement (arrows) and temperature (colour) in the top five metres of water during January from 2003 to 2010. The size of the arrows indicates relative speed of the currents. Note how the water moves in different directions at various parts of the coast.
Data – Provided from the Pilbara Marine Conservation Program (PMCP) ROMS model on a nominal 1km grid developed and provided by PMCP at CSIRO.









Above Dugong feeding on *Cymodocea serrulata*.
Photo – Kelvin Aitken/Marinethemes.com

Right
A) An example of three self-recruiting systems, suggesting low resilience to natural or anthropogenic disturbance.
B) An example where Montebello/Barrow Islands are self-recruiting, but Exmouth Gulf and Ningaloo are well connected so have greater recovery potential in the face of disturbance than perhaps Montebello/Barrow Island.
C) All three locations are connected in a well-connected system that would have the greatest ability to recovery from external impacts.

can move up or down to take advantage or avoid certain bodies of water to enhance or impede their dispersal.

Meanwhile, juvenile fish, less than a centimetre long, can swim quite strongly against or with currents to impede or aid dispersal, in a strategy known as 'active dispersal'. This is quite amazing given their tiny size as not all vertebrates have active dispersal; for example hatchling turtles are not strong enough to control their dispersal and are sometimes dragged by currents from the tropics all the way south past Perth. Interestingly, water carries chemicals and sounds great distances through the ocean, and juvenile fish use their sense of smell and hearing to locate reefs from up to several kilometres away.

TEMPORAL SCALES OF CONNECTIVITY

We can measure connectivity on varying spatial scales ranging from individual movements, to intergenerational movements all the way up to geological timescales of connectivity. Individual movements are typically measured using parentage or assignment tests. Comparing the babies' DNA to that of a number of potential parents, similar to what we do in humans to confirm paternity. These are direct measures of connectivity. Intergenerational movement studies focus on how related a number of populations from different locations are to each other to confirm a relative amount of connectivity. That is populations from location X and Z have more genetic similarities than location X and Y, therefore there is more transfer of genetic material (babies) between X and Z than X and Y. Studies on geological timescales are used to reconstruct lineages and understand where species have come from, and to infer how and where they may have survived during long periods of disturbance, such as ice ages where the seas were reduced dramatically compared to present sea levels. While these questions are important, managers, tour operators and the general public are more likely to be interested in questions of smaller time scales such as: "If the coral

Above left Collecting seagrass.

Above A cleaner shrimp.
Photos – Richard Evans/Parks and Wildlife

in my local reef or marine park bleaches and dies, how long will it take to recover to its original state, and where will it come from?" Genetic techniques have only recently become affordable to conduct such short time-scale projects (years to decades), which are important for short-term management issues. So now is the ideal time to start searching for answers to such questions on the Western Australian coastline. While science is interested in all scales of connectivity, most projects are carried out over two to five years, which focuses on short-range data collection.

LEVELS OF CONNECTIVITY REFLECT RESILIENCE

Interconnectedness provides a challenge for the agencies and groups managing WA's marine environment. To understand the recovery potential of any location in the event of disturbance, marine park or otherwise, we need to study the connection within and between marine parks, as well as to and from areas surrounding each park, and determine which areas are more or less susceptible.

Some areas rely on what we call 'self-recruitment' – that is, all the new offspring arriving in that area actually come from that area. Only recently was evidence shown to support this phenomenon in the Great Barrier Reef, Hawaii and the Caribbean, and it is now believed to be quite common in the marine environment. However, a self-recruiting system is the least resilient to disturbance. Let's use WA's Ningaloo Marine Park as a hypothetical example: if species within Ningaloo Marine Park were totally self-recruiting and the area was adversely impacted, the park has less chance of recovering to its original state. Or, if all the offspring came from only one other area, and both areas were impacted, then Ningaloo reef would also have a lower chance of recovery. This scenario offers more resilience than the self-recruiting park, but in a world where heatwaves and large cyclones are forecast to increase in frequency, this model may still be susceptible due to the regional scale of these impacts.

The best-case scenario would be a network of several source populations interconnected to and from Ningaloo, including self-recruitment, to ensure the greatest resilience in our management. These are the types of questions we hope to answer in a current Parks and Wildlife study funded by the Chevron-operated Wheatstone project.

FOCUSING ON THE PILBARA

Parks and Wildlife is carrying out the Wheatstone Connectivity Offset project in the Pilbara – a region with increasing natural and man-made impacts – with the aim of understanding the connectivity of benthic habitats and the animals that use them (see also 'Dampier Achipelago underwater: A diamond in the red rock' on page 16). Using a new population genomic technique, department scientists, along with collaborators from the Department of Fisheries, Edith Cowan University, CSIRO, The University of Western Australia, Western Australia Museum and Curtin University, is studying marine life with different dispersal and reproductive characteristics to test for similarities or differences in population connectivity between key taxa, including corals, seagrass, mangroves and fish, over varying spatial scales, from the Kimberley to Bunbury. This information is critically important for managing this precious environment, as it provides background for planning marine protected areas, assists management of fisheries and nursery stocks, and enables industry to plan projects in a way that will minimise impacts on sensitive areas. Field work for the project has finished and the lab work has begun. Research outputs are expected to begin in the next year or so. And, while we process the data, and learn more about these magnificent ecosystems, we will happily engage with people of all walks of life who want to learn more about what we're doing. Who knows, they might even encourage us to view things in a different way or remind us that "they're all connected mate" in one way or another.

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