Marine areas that provide food: Indicator document - Ecosystem Service Modelling & Rule-base development

Indicator	CICES classification
MARINE FOOD PROVISION **Marine areas that provide food (Marine food (Provision)**	**Section**: Provisioning **Classes:** • Wild plants, algae and their outputs • Wild animals and their outputs • Plants and algae from in-situ aquaculture • Animals from in-situ aquaculture. **CICES IE Sub-class:** Multiple classes (see CICES for Ireland_fordb.xlsx for details)
Scale	**CICES Cascade Level** [1]
Strategic/National/~~Regional/Local~~	~~Structure/Function/~~Service/~~Benefit/Value~~

[1] Potschin, M. and R. Haines-Young (2016): Frameworks for ecosystem assessments. In: Potschin, M., Haines-Young, R., Fish, R. and Turner, R.K. (eds) Routledge Handbook of Ecosystem Services. Routledge, London and New York, pp 125-143.

What the service is

This service includes everything taken from the sea for human consumption. This includes fish (marine and diadromous), shellfish, crustaceans and algae, both from wild harvest and from aquaculture.

The scientific framework outlined below helps to determine the type of data that could be used for modelling of this service, and provides general guidance which indicators are likely to have a positive or negative impact on service provision.

Scientific framework for modelling 'marine food provision'

Overview:	The oceans provide an important source of food to coastal communities and underpin economies around the world (Cochrane et al., 2009). Fishing is an important food provisioning activity providing a fundamental ecosystem service (Makino and Sakurai, 2014) through the harvesting of wild and farmed finfish, molluscs and shellfish (hereafter referred to collectively as "fish"). Fish harvesting locations range from shallow to deep water environments and are conducted by a variety of methods from small-scale artisanal fishing practices to large-scale trawling and aquaculture enterprises (Sewell and Hiscock, 2005). Fish stocks for food provisioning are controlled by a number of factors, which include water column properties, habitat, development opportunities, and management restrictions. Marine aquaculture (mariculture) also provides food provisioning services through the cultivation of saltwater plants/algae, most commonly macroalgae. The aquaculture industry has grown by 8.7% per year since 1970 – three times faster than agriculture (Diana et al., 2013). This makes it a fundamental contributor to the food provision service.
Water	Water properties are important considerations for marine food provision. Some of the most important supporting functions for marine food provision are nutrients/organic load, turbidity/suspensoids, sea temperature, currents, salinity, and sources of pollutants. The role of nutrients and organic compound load in the water column is accepted as fundamental in determining growth and development of algae, which underpin wild and farmed fisheries and plant/algae aquaculture (Whitney et al., 2005). Turbidity describes the optical properties of a liquid which causes light to be scattered, reducing water clarity. Suspensoids include organic or inorganic solid or colloidal particles held in suspension within a liquid. The effects of turbidity and suspensoid load in the water column can have wide ranging implications on fish stocks. In some instances, high turbidity can reduce marine fish stocks by hindering fish growth (both first maturity and maximum size), deoxygenizing the water column, clogging gills, reducing visibility of pelagic food, and by providing extra habitat for photophobic fish. Conversely, reduced visibility may increase fish survival

	rates by allowing concealment from predation/reducing aerial predation risk (Bruton, 1985; Kaartvedt et al., 1996). Currents provide a wealth of functions affecting fisheries and aquaculture by exchanging water. This a) changes nutrient availability (Whitney et al., 2005); b) provides a source of herbivorous food (plankton input); c) oxygenates the water column; d) provides a source of larval recruitment; e) propagates cool, nutrient rich water from poles or deep water; and f) provides an input of sediment (Crawford and Thomson, 1991). The above processes are essential supporting functions for marine food services. Water motion improves seaweed nutrient uptake and removes epiphytes and waste products (Diez et al., 2003). Salinity is essential for the spawning success of some fish species, where hyper-osmotic conditions are required (Westin and Nissling, 1991). Low salinity can dramatically impact the populations of shellfish (i.e. oysters) (Hofmann and Powell, 1998).
Habitat	Fisheries habitats are both complex and varied, and often species-dependent. Unlike terrestrial habitats, marine habitats tend to exist in a three dimensional setting, where the water column acts as much a part of the habitat as the substrate, geology and biology present on them. A positive relationship exists between sediment depth and the abundance of macrophytes, where macroalgae abundance increases with increases in sediment depth (Zieman et al., 1989). Roots are more readily established in fine grained sediments and may increase aquaculture success. Benthic structure may provide refuges for fish in areas where seabed relief is highly complex (Thayer and Chester, 1989), enhancing the chances of fish reaching maturity and maximum size, in turn increasing wild fish biomass. Bays, reefs and lagoons also provide areas with fish refuges and reduce damage to macroalgae by wave action. Light attenuation through the water column directly affects the photosynthetic efficiency of macroalgae, limiting cultivation, typically occurring at depths <20 m (Quartino et al., 2001). Photic zones dictate the distribution of fish (especially the distribution of photophobic/photophilic fish), which are depth dependent. Species richness for macroalgae tends to decrease at depths greater than 20m, probably due to light attenuation limiting photosynthetic efficiency (Quartino et al., 2001).

Other Effects	Primary productivity has a positive correlation with fish standing stock (Nriagu et al., 1990), particularly with phytoplankton production and the concentration of chlorophyll-α (Downing et al., 1990). These could be measured by using the Normalised Difference Vegetation Index (NDVI) in marine remote sensing imagery.
Management	Management leading to reduced biodiversity includes: • Mono-species cultivation reducing biodiversity, thus reducing natural habitat for wild faunal biomass for food provision • By-catch: fisheries waste product removed from breeding stocks but not utilised as marine food. • Environmental degradation associated with fishing techniques (i.e. bottom trawling) altering natural habitats for wild faunal biomass for food provision. • Unsustainable mariculture: pollution (faecal material, uneaten food, nutrients, and chemicals and drugs like pesticides, disinfectants and antibiotics) negatively impacting wild fish stocks (Cao et al., 2007); requirement of live feed for carnivorous farmed fish stocks reducing wild marine faunal stock (Benetti et al., 2006). Management, leading to increased biodiversity includes: • Sustainable fisheries practices that ensure fisheries stocks for long-term marine food provision. In 2008, 46% of fish, crustaceans and molluscs consumed by people were sourced from aquaculture projects (Jensen et al., 2014), and, as property rights strengthen for aquaculture, the aquaculture industry will invest in new technology to improve aquaculture efficiency (Anderson, 2003).

Supporting evidence: References

Anderson, JM, 2003. The international seafood trade. Woodhead Publishing Limited, Cambridge England. ISBN 978-1-85573-456-2

Benetti, D., Brand, L., Collins, J., Orhun, R., Benetti, A., O'Hanlon, B., Danylchuk, A., Alston, D., Rivera, J. and Cabarcas, A., 2006. Can offshore aquaculture of carnivorous fish be sustainable. *World Aquaculture*, 37(1), pp.44-47.

Bruton, M.N., 1985. The effects of suspensoids on fish. *Hydrobiologia*,125(1), pp.221-241.

Cochrane, K., De young, C., Soto, D. and Bahri, T., 2009. Climate change implications for fisheries and aquaculture – Overview of current scientific knowledge. *FAO Fisheries and Aquaculture Technical Paper 530.*

Crawford, W.R. and Thomson, R.E., 1991. Physical oceanography of the western Canadian continental shelf. *Continental Shelf Research*, 11(8), pp.669-683.

Diana, J.S., Egna, H.S., Chopin, T., Peterson, M.S., Cao, L., Pomeroy, R., Verdegem, M., Slack, W.T., Bondad-Reantaso, M.G. and Cabello, F., 2013. Responsible aquaculture in 2050: valuing local conditions and human innovations will be key to success. *BioScience*, 63(4), pp.255-262.

Dıez, I., Santolaria, A. and Gorostiaga, J.M., 2003. The relationship of environmental factors to the structure and distribution of subtidal seaweed vegetation of the western Basque coast (N Spain). *Estuarine, Coastal and Shelf Science*, 56(5), pp.1041-1054.

Downing, J.A., Plante, C. and Lalonde, S., 1990. Fish production correlated with primary productivity, not the morphoedaphic index. *Canadian Journal of Fisheries and Aquatic Sciences*, 47(10), pp.1929-1936.

Hofmann, E.E. and Powell, T.M., 1998. Environmental variability effects on marine fisheries: four case histories. *Ecological Applications*, 8(sp1), pp.S23-S32.

Jensen, F., Nielsen, M. and Nielsen, R., 2014. Increased competition for aquaculture from fisheries: Does improved fisheries management limit aquaculture growth?. *Fisheries Research*, 159, pp.25-33.

Kaartvedt, S., Melle, W., Knutsen, T. and Skjoldal, H.R., 1996. Vertical distribution of fish and krill beneath water of varying optical properties.

Makino, M. and Sakurai, Y., 2014. Towards integrated research in fisheries science. *Fisheries science*, 80(2), pp.227-236.

Nriagu, J., Holdway, D. and Corker, R., 1990. Control of marine fish production. Limnol. *Oceanogr*, 35(7), pp.1593-1604.

Quartino, M., KloÈser, H., Schloss, I. and Wiencke, C., 2001. Biomass and associations of benthic marine macroalgae from the inner Potter Cove (King George Island, Antarctica) related to depth and substrate. *Polar Biology*,24(5), pp.349-355.

Thayer, GW. And Chester, AJ., 1989. Distribution and Abundance of Fishes Among Basin and Channel Habitats in Florida Bay. *Bulletin of Marine Science*, 44(1), pp. 200-219(20).

Westin, L. and Nissling, A., 1991. Effects of salinity on spermatozoa motility, percentage of fertilized eggs and egg development of Baltic cod (Gadus morhua), and implications for cod stock fluctuations in the Baltic. *Marine biology*, 108(1), pp.5-9.

Whitney, F.A., Crawford, W.R. and Harrison, P.J., 2005. Physical processes that enhance nutrient transport and primary productivity in the coastal and open ocean of the subarctic NE Pacific. *Deep Sea Research Part II: Topical Studies in Oceanography,* 52(5), pp.681-706.

Zieman, J., Fourqurean, J.W. and Iverson, R.L., 1989. Distribution, abundance and productivity of seagrasses and macroalgae in Florida Bay. *Bulletin of Marine Science*, 44(1), pp.292-311.