



Sustainability, equity and welfare: A review of the tropical marine ornamental fish trade

Ditch Townsend¹

Abstract

About 27 million tropical marine ornamental fishes are traded each year. Of these, 80% come from Indonesia, the Philippines, the United States, and Sri Lanka. Over 80% go to North America, the European Economic Area, Switzerland and Japan. The trade depends on wild capture, but is becoming increasingly supplemented by aquaculture-produced ornamental species. The trade has impacts on three core areas: 1) habitat integrity and biodiversity of tropical marine ecosystems (**sustainability**), including the genetic diversity within individual species; 2) development of coastal communities related to practice safety, economic sustainability, food security, and trade fairness (**equity**); and 3) mortality, morbidity and husbandry of the fishes being cultivated and traded (**welfare**). There are numerous solutions to identified problems, but efforts to date have focused predominantly on voluntary certification or legislation. However, problems have not been adequately defined, and solutions have not been sufficiently explored to be confident about all policy recommendations or decisions. New analytical tools yet to be used include topic mapping and the DPSIR (driving forces, pressures, states, impacts and responses) framework. This review is an attempt to provide a comprehensive update on the trade and to suggest new ways forward, with an emphasis on the Pacific Ocean region for production, and the United Kingdom for consumption.

Introduction

Context

The ornamental tropical marine fish trade is set in the context of mainstream conservation (Balmford and Whitten 2003), natural resource management (Glaser et al. 2010), and the trades in ornamental freshwater fishes (Gerstner et al. 2006), ornamental invertebrates (Rhyne et al. 2009), marine curios (Grey et al. 2005), and live reef food fishes (Scales et al. 2007). Analogous labelling initiatives include the generic fair trade movement (FLO 2010), and for seafood, the Marine Stewardship Council (Gulbrandsen 2009) and the Aquaculture Stewardship Council (Dickson 2010).

Scale of the trade

Using government statistics, published scientific articles, grey literature and personal contacts, Wood (2001) estimated the global number of fishes exported to be 11–20 million and the number of fishes imported to be 25–40 million per year (different datasets and a lack of tracking information led to differing estimates). While Wood is frequently cited, she notes that her estimates are “very rough”

and “should be treated with caution.” She was subsequently misquoted in an extensively cited chapter by Green (2003) who mistook her catch estimates of 14–30 million fishes (including those dying before export) as her trade estimates.

A Global Marine Aquarium Database (GMAD) launched in 2002 was designed to capture accurate trade data (Green 2003), but data entry stopped after one year. The United Nations Environment Programme, using data for 1998–1999 from importers and data for 2000–2001 from exporters, estimated that 20–24 million fishes were traded annually (Wabnitz et al. 2003). The United Nations’ estimation method was unclear but required an extrapolation of data representing less than 0.5% of their lowest estimate. However, the Ornamental Aquatic Trade Association (OATA¹) states that GMAD data are “still probably the best available” (Keith Davenport, Chief Executive, Ornamental Aquatic Trade Association, pers. comm. 2009). The European Union (EU) commissioned a consultation on improving trade statistics related to EU imports of tropical marine fishes (UNEP-WCMC 2008). There has been no outcome since the report’s submission. Plans are underway in the United States (USA) to improve their trade data (Cooper and Best 2009).

¹ Email: ditchtow@gmail.com

² <http://www.ornamentalfish.org/>

Combining prior estimates with up-to-date key informant knowledge, but without using the available data accessed by Smith et al. (2008), Zajicek et al. (2009) estimated that 20 million fishes are traded annually. Compounding the criticisms of earlier estimates (which Zajicek et al. rely on), is the fact that key informant data were not published, so their assumptions are unknown, and being anecdotal, the estimates cannot be statistically validated.

USA import data for 2000–2005 show that the average annual import of ornamental fishes (marine and freshwater) for this period was 187 million, although the authors note “poor record keeping at ports” (Smith et al. 2008). Detailed 2005 data indicate that 8% (nearly 15 million when back-calculated) were

marine fishes. Combined with GMAD data (Green 2003), and noting that 61.4% of tropical marine ornamental fishes were traded in North America, a rough recalculated global estimate increases to 24.4 million (excluding the 4.3% shipped within but not “imported” from USA waters). Incidentally, the GMAD itself apparently excludes data from Japan. With suggestions that the Japanese market accounts for at least 10% of global imports (Wood 2001), a final roughly recalculated global estimate is 27 million tropical marine ornamental reef fishes traded annually.

The relative scale of exports among countries (Wood 2001) is shown in a density equalisation map³ (Gastner and Newman 2004); in Figure 1, the darker

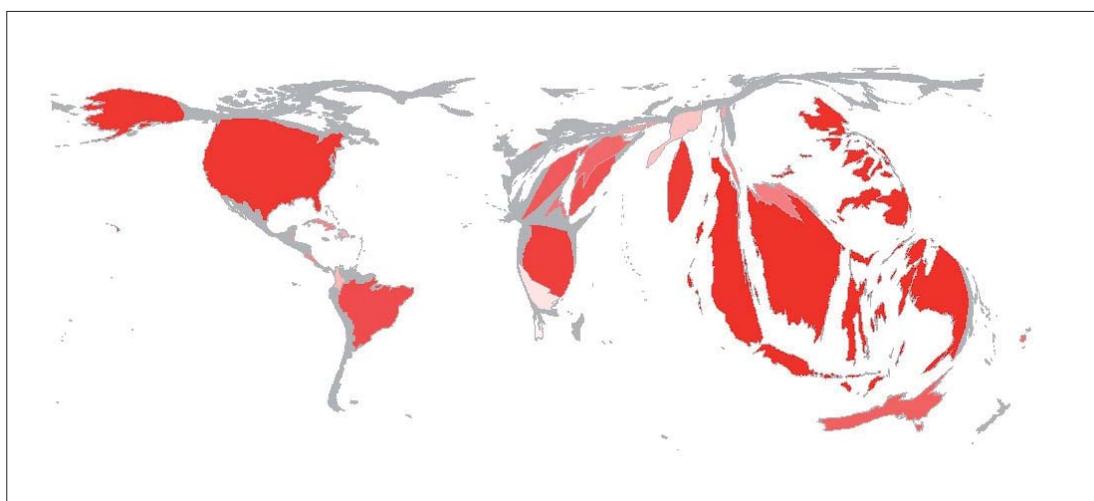


Figure 1. Density equalisation map for exports of tropical marine ornamental fishes, by country (produced by the author using open source Mapwindow™ GIS and ScapeToad software).

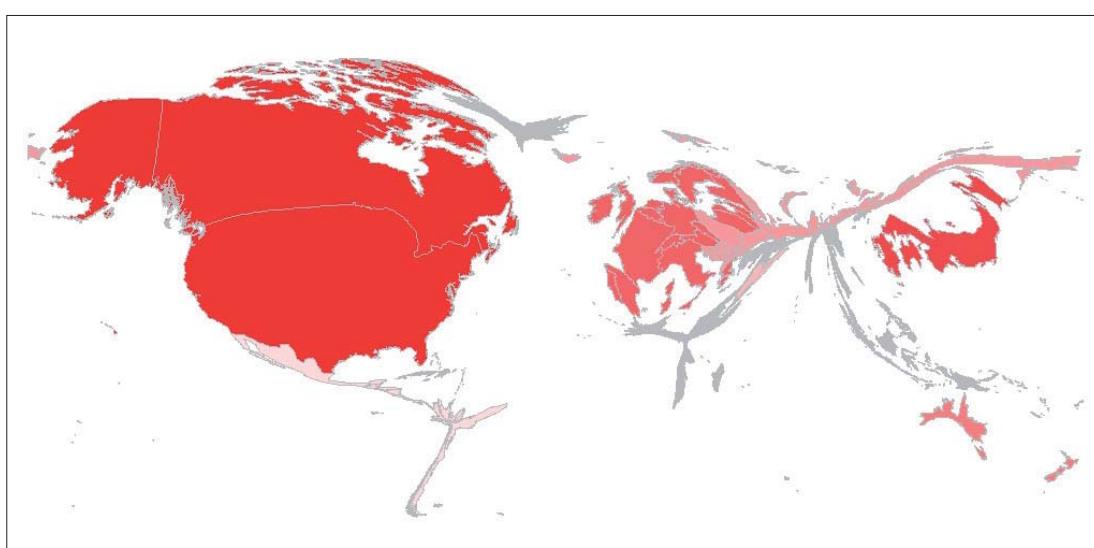


Figure 2. Density equalisation map for imports of tropical marine ornamental fishes, by region (produced by the author using open source Mapwindow™ GIS and ScapeToad software).

³ A density equalisation map adjusts the sizes of map areas (in this case the world's countries or regions) to match some form of relative data — in this case their exports (and in Figure 2, their imports) — without changing their positions relative to each other.

the colouration, the greater the rate of export. The relative scale of imports across regions, from Green (2003) supplemented by Rhyne et al. (2009), has been similarly mapped in Figure 2, and assumes that an additional 10% goes to Japan. Recent unpublished data, not reflected on this map, suggest that China has now joined the USA, the European Economic Area and Japan in the top ranks of marine ornamental fish importers (Zajicek et al. 2009).

Scope of the trade

Capture

The main source of fishes is the capture of adults on coral reefs (Reksodihardjo-Lilley and Lilley 2007; McCollum 2007). Cyanide use — previously common across the Philippines and now increasing in Indonesia — can have a devastating impact on collected fishes (up to 75% may die in transit as a result), uncollected fishes, corals and other invertebrates (McCollum 2007). More sustainable techniques involve fine-mesh hand nets and mist nets. However, their use can significantly damage coral — mist nets when snagged, and either one when used in company with sticks or rocks to break coral refuges. So-called “non-destructive” techniques have also been criticised because excessive fishing pressure can significantly alter local population structures, at least in species with no pelagic dispersal mechanism (Kolm and Berglund 2003).

Culture

Most reef fishes produce pelagic larvae, only a minority of which can find a suitable reef before dying. The vast majority of larvae that reach a reef are eaten by predators prior to settling, and this high pre-settlement mortality makes pre-settlement harvest significantly less environmentally damaging than the harvest of equivalent numbers of settled adults (Dufour 1997). Export resilience is highest in young adults; without local post-capture culture, juvenile harvest is almost worthless. Additionally, post-larval rearing enhances future acclimatisation because fishes will then be accustomed to artificial food (Lecchini et al. 2006). However, Bell et al. (2009) note that while post-larval capture and culture can benefit smaller scale or artisanal enterprises near export hubs, its commercial viability is reduced by the huge and often unpredictable fluctuations in available species and quantities within a given locale, leading to mismatches of supply and demand. There is also a risk to isolated island fish communities dependant on local replenishment rather than pelagic dispersal.

Hayes (2009) states that to date, less than 150 tropical marine ornamental fish species have been bred, while more than 1,300 species are currently traded

but awaiting viable culture protocols. This is close to the estimate offered by Zajicek et al. (2009) of 1,500 fish species in the marine ornamental trade. Koldeway and Zimmerman (2007) note, however, that nearly 300 of approximately 700 marine species bred have been bred over multiple generations. The Marine Ornamental Fish and Invertebrate Breeders Association has Internet forums dedicated to 21 different bony fish families, as well as notes on 11 other families, alongside a dedicated forum discussing shark and ray breeding (MOFIB 2010). But apart from a core of highly popularly bred marine fishes (e.g. the anemonefish *Amphiprion percula*), the vast majority of individual fishes bought by hobbyists are wild-caught.

Pomeroy et al. (2006) examined the option of small-scale aquaculture in countries that normally only harvest adults. High investment costs limit this option's likely viability. Large-scale breeding in wealthier countries (Wu 2009), with small-scale enterprises providing broodstock in the fishes' native countries, is more viable economically.

Trade structure

Zajicek et al. (2009) have examined the marine ornamental trade pathway as it applies to Florida, but it remains a useful template for understanding the structure of the whole trade. Essentially, collectors and culturists supply exporters, often with at least one intermediate buyer or broker (Reksodihardjo-Lilley and Lilley 2007). Importers then sell wholesale to retailers, who sell to consumers. Crucially, survival after final purchase depends on a fish's health when bought. This is itself related to retail quarantine practices. The hobbyist's skill plays a later, but important, role too (McCollum 2007).

Analyses of power and resource distribution in live reef fish food chains in the Pacific offer analogies that probably also apply to marine ornamental fishes. These include an inequitable balance of information, risk and investment, the conservatism of primary producers, and market fluctuations (Muldoon and Johnston 2006).

While wholesalers undoubtedly hold detailed data regarding sales to retail clients, such data are kept commercially confidential. When writing directly to 435 British aquarium retailers regarding marine ornamental polychaete worm sales, Murray (2010) obtained zero initial responses, and after 45 retailers were given a telephone follow-up, only two eventually provided any written data.

Very little research has directly involved hobbyists. Most recently, Murray (2010) received 314 responses from marine hobbyists to a self-selecting, United Kingdom (UK)-oriented, online survey. Of the six

pre-defined purchase factors (including “Compatibility”, “Looks good”, “Easy”, “Price” and “Function”), “Local shop recommended” was most often the lowest priority. Information from retailers about an animal’s source was desired by 91%, and 55% had heard of the Marine Aquarium Council (MAC). Furthermore, 97% would be prepared to buy a cultured animal at a price premium. Notwithstanding a willingness to pay more for sustainably caught wild fishes, another study suggested that hobbyists who were aware of MAC “revealed a strong lack of credibility for the MAC program and a higher confidence in alternatives,” preferring either tank-bred fishes or survival guarantees (Alencastro et al. 2005). But McCollum (2007) found that hobbyists in the USA were often ignorant of MAC.

In the USA, Zajicek et al. (2009) quote data from the American Pet Products Manufacturers Association annual consumer survey of 2007–2008, estimating that 800,000 households keep a tropical marine aquarium, each with an average of 12 fishes (around 10 million held at a time). However, Zajicek et al. note that around 9% of these fishes may have come from friends and relatives (some through home breeding). Assuming that: 1) 60% of the global trade reaches the USA, 2) all imported fishes are sold, 3) 20 million fishes are globally imported, and 4) commercial sales represent the remaining 91% of hobbyist fishes, the average turnover, and hence life expectancy, in hobbyist captivity would be around 8 months.

Additionally the Natural Resource Management Ministerial Council (NRMMC) (2006) of Australia quotes unsourced data for the UK, suggesting that 40% of fishes are kept by 7% of hobbyists. A power-law distribution in keeping with the Pareto principle and based on this figure would suggest that one-third of hobbyists keep two-thirds of fishes. It is not known whether turnover rates are similar among hobbyists.

The other significant consumer of imported marine tropical ornamental fishes is the public aquarium sector, although Koldeway and Zimmerman (2007) at the London Zoo suggest that “compared to the hobbyist market, public aquaria are minute consumers”. Being regulated under zoo legislation, and viewing healthy fishes being the reason the public attend, public aquarium fish welfare is closely monitored in the UK. It is not certain, however, how many public aquaria have gone as far as the London Zoo, which has a comprehensive Sustainable Acquisitions Policy. This incorporates MAC standards as minimum expectations for wild-caught display organisms, but allows for species rescue-breeding and re-homing of Customs seizures. Additionally, cultured fish can be considered, with a preference

for farms in fishes’ native countries. The authors note that, “There is a balance between the issues of welfare of fish handling and transport, and the capture impact sustainability.”

Lastly, USA authorities believe that organised crime is a significant threat arising from the marine aquarium trade (Cooper and Best 2009), with the potential to distort the structure and transparency of the trade. No data on the subject have been published, however, so it is difficult to make an independent judgement.

Impacts

Sustainability

Well documented examples of ornamental collecting pressures threatening full species extinction are rare. The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) presently lists no such species, not even Indonesia’s Banggai cardinalfish, although at least one attempt has been made to list it (Vagelli 2008). However, local or regional vulnerability is possible (Teitelbaum et al. 2010) and can be ascertained using a tool validated by Roelofs and Silcock (2008).

Cyanide is frequently used to assist with the capture of tropical marine aquarium fishes but it can kill or damage coral *ex-situ* in the doses regularly used (Jones 1997), with the attendant risk of irreversible habitat change at damaged reefs that comes from algal over-colonisation of dead coral. Initially used primarily in the Philippines, its use is widespread in Indonesia, with multiple negative impacts on ecosystems, fishes exported, and collector communities (McAllister et al. 1999). The situation is worsened when collectors use surface compressor piped air (“hookah”), which allows longer and deeper dives than free or scuba diving (Pet and Djohani 1998).

In importing countries with tropical or subtropical zones, such as Florida and Hawaii in the USA, significant social and political arguments exist to severely limit aspects of the trade relating to non-indigenous, or exotic, fish species, although there are questions about its real economic and ecological impacts (Zajicek et al. 2009). The Indo-Pacific lionfish invasion of the Caribbean is the most quoted ecologically damaging example (Albins and Hixon 2008). In Australia, Whittington and Chong (2007) have gone so far as to call for “the number of species traded and the number of sources permitted ... to be dramatically reduced to facilitate hazard identification, risk assessment and import quarantine controls,” not least for fear of disease spreading to indigenous species.

Equity

The livelihood value to artisanal communities of collecting for the marine ornamental fish trade, and community capacities to manage the natural resources that they control, have been catalogued in Indonesia (Reksodihardjo-Lilley and Lilley 2007; EC-PREP 2004), Fiji (Teitelbaum et al. 2010) and the Philippines (Vincent 2008). Where community-based natural resource management mechanisms are controlled by external, dominant stakeholders, reef fish overexploitation can simply become locally sanctioned (Thorburn 2003), and collectors can become exploited and indebted to the buyers they depend on. The additional problems of death and injury related to poor diving technique and equipment are carefully explained by McCollum (2007).

Welfare

Post-capture holding and transport are critical steps in the trade. Schmidt and Kunzmann (2005) estimated mortality rates at between 10% and 40% prior to export from a facility in Bali, Indonesia. This is far greater than MAC's target of less than 1% at each step in the trade. Much could be done to reduce export-related mortality from estimates that reach as high as 30% (Rubec and Cruz 2005): Temperature maintenance and available oxygen could be improved; fish densities and light ambience could be lowered; and chemicals could be added to buffer pH, neutralise ammonia, inhibit bacteria, and sedate fishes. Even accessing timely transport can be a significant problem (Teitelbaum et al. 2010).

Little appears to have been published regarding distributor or retailer husbandry outcomes, although OATA has published guidelines for members (OATA 2000) and offers training to retailers and local authority pet shop inspectors in the UK. Even less appears to have been published about hobbyist husbandry outcomes, although specific supportive resources have been published (Wood and Dakin 2003; Fenner 2008).

Responses

Certification

MAC was established to certify services for all parts of the tropical marine aquarium retail trade. Intended to have a comprehensive impact, Core Standards were developed for: 1) Ecosystem and Fisheries Management; 2) Collection, Fishing and Holding; and 3) Handling, Husbandry and Transport (Alencastro et al. 2005; Shuman et al. 2004).

Reksodihardjo-Lilley and Lilley (2007) describe some of the benefits of MAC-certified links for fishermen collecting in Indonesia. However, significant criticisms of ornamental fish certification initiatives from as early as 2006 regarding poor cost-benefit ratios, industry resistance, and lack of consumer demand have been the subject of very public assertions (Tlusty et al. 2006).

Criticisms of MAC programme strategy, and public revelations of major partnership challenges, have both emanated from a major donor evaluation: "Overall, the strategy of transforming the industry through the MAC certification of the entire chain of custody is not working... The partnership between the three organizations (MAC, RCF⁴ and CCIF⁵) is dysfunctional" (Bellamy and Winsby 2008). Anticipating this review, MAC's leadership changed in 2007 (Mainenti 2007), and four major developments resulted. The first has been an increasingly proactive stance by the USA government. Second is the initiation of a new European organisation: the Sustainable Aquarium Industry Association (SAIA), formally registered in late 2009, which hopes to provide monitored certification for retailers (Hayes 2008). The third development is that MAC has instituted changes, leading to a new, more accessible initiative for retailers — the Licensed Retailer Program (Mainenti 2009). It is worth noting that the UK has had only one MAC-accredited retailer, and it no longer operates. UK hobbyists now have great difficulty identifying the provenance of fishes in the average shop (Hayes 2008). The fourth development is the proposal, emerging from a workshop in Noumea, New Caledonia in December 2008, to develop a specific "Pacific Eco-Certification" programme (Teitelbaum et al. 2010).

Despite early promise, freshwater tropical fish certification initiatives have never made much progress (Chao and Prang 1997; Bicknell 2004). At present, the freshwater tropical fish sector looks to breeding for much of its sustainability, and to MAC for lessons in self-certification, although it has been suggested that the Forest Stewardship Council (FSC) might be more appropriate (Tlusty et al. 2006). As such, the marine tropical ornamental trade can learn little from certification efforts in the tropical freshwater domain.

It is worth noting the range of criticisms aimed at MAC's analogue — MSC — which has been accused of: 1) certifying fisheries that are not really sustainable (Dickson 2010); 2) not providing a sufficient financial incentive to fishermen; 3) remaining

⁴ Reef Check Foundation

⁵ Conservation and Community Investment Forum

out of touch with consumers (Goyert et al. 2010); 4) being insufficient to halt declines in fish stocks (Gulbrandsen 2009); and 5) marginalising small-scale producers (Ponte 2008). This is despite the initially assessed environmental benefits of MSC (Agnew et al. 2006). The whole certification initiative has, from the beginning, also been relegated in the eyes of some in the mainstream conservation world to a welcome, but insignificant, role (Balmford and Whitten 2003).

Also worth noting is the position of the 24 existing Fairtrade Labelling Organisations (FLOs) on certification. In their own words, "FLO is the only certification scheme that sets out to tackle poverty and empower producers in developing countries. Other schemes have as their focus 'protecting the environment' or 'enabling companies to trace their coffee'. They don't claim, or set out, to help producers improve the quality of their lives and take more control over their futures" (FLO 2010). While FLO operates with generic trade and producer standards, they have yet to develop any product standards specific to live animals. There have also been a number of criticisms levelled at Fairtrade in recent years, almost all of which are economic. Four key criticisms, rebutted by the Fairtrade Foundation (2008), are that: 1) member producers benefit at the expense of non-members; 2) less needy farmers have preference over more needy ones; 3) Fairtrade perpetuates a cash-crop farming poverty trap by reducing diversification; and 4) there are preferable ethical approaches to trade.

Legislation

The USA government is less sure now about the hopes for effective voluntary controls than it was at the start of this millennium when its Coral Reef Task Force suggested that, "after working with stakeholders over a specified time period, the U.S. should prohibit the import or export of any coral reef species unless accompanied by certification that the products were not taken through the use of destructive fishing practices" (quoted by Lieberman and Field 2001). While recognising the need to educate consumers more effectively, they now note: "Previous attempts to redefine the trade without legislative intervention have stumbled partially due to a lack of a clear understanding of the nature and scope of the industry as well as the behavior of players in the market". Indeed, they are prepared to state that, "a large percentage of the trade is currently in violation of existing laws...in the U.S. governing illegally harvested imports" (Cooper and Best 2009). While also alleging "the continued failure of CITES," a

recent USAID⁶-organised workshop proposed that USA laws need reforming (incorporating import, wholesale and retail licensing elements), and USA enforcement needs improving (Tissot et al. 2010). The USA dominates the marine ornamental export market, so significant changes to its import regime would have similar effects on other markets.

In the UK and Europe, a number of proposals have been made or implemented regarding regulating the marine ornamental trade, including one call for all imports to be certified (Taber 2008). The Swiss now appear to have the strongest welfare laws to cover fishes kept by hobbyists (Swiss Confederation 2008), with interpretations indicating that certain fishes are now required to be kept in social groups, and aquariums must have at least one opaque side (Pancevski 2008). UK animal welfare law makes no direct reference to hobbyist fish keeping but, as vertebrates, fishes are clearly protected from unnecessary suffering and an owner has a duty to "take such steps as are reasonable in all the circumstances to ensure that the needs of an animal for which he is responsible are met to the extent required by good practice", and mention is specifically made of "any need it has to be housed with, or apart from, other animals" (United Kingdom Parliament 2006). Research by Saxby et al. (2010) implies that even in the UK, there might already be a duty for hobbyists to keep social fishes in shoals.

Public aquariums are covered by specific zoo legislation (United Kingdom Parliament 1981), as are pet shops (United Kingdom Parliament 1983), and international fish transport is covered by the International Air Transport Association's Live Animal Regulations (IATA 2010), while EU Wildlife Trade Regulations stipulate other reporting and licensing requirements, including those for CITES (TRAFFIC Europe 2009).

Management

Rhyne et al. (2009) have called historical fisheries management "inexact and reactionary... often taking action only after a critical stock suffers overfishing or collapse." They note the need to switch from reactive to adaptive control. Notably, adaptive approaches for marine aquarium collecting have been the legislated norm in Hawaii for 20 years (Tissot 1999), and commercial practise in Fiji for longer (Teitelbaum et al. 2010). Kingsford et al. (2009) go further, recommending that ornamental fish exports should all require licences and only involve bred or sustainably managed natural stocks.

⁶ US Agency for International Development

While ecosystem-based management has been promoted for the supply side of the trade (Tissot et al. 2010), the interaction of official marine management systems such as marine protected areas and locally derived natural resource management can have counter-intuitive outcomes and care should be taken to fully understand proposed management areas and outcomes (Glaser et al. 2010).

Opportunities

Ontology

The internationally standardised topic mapping method (ISO 2003) allows all issues within a domain to be mapped, using the dimensions of topic and association (Pepper 2002). Initially, an ontology must be developed for the domain in question (Garshol 2007). A topic map can then be built and used for indexing instances of opinions, themselves sought through interviews, journal articles, and Internet-based opinion mining (Pang and Lee 2008). A topic map allows various features of issues to be consistently explored, including the polarity, extent, strength and necessity of opinions, alongside asserted or actual trends. However, there does not appear to be an ontology of the ornamental tropical marine fish trade domain, which could enable a clear and simple topic map of the issues to be built. Research is needed to lay the foundation for comprehensive opinion analyses, by defining the layout of a comprehensive, domain-specific topic map, allowing priorities, opportunities, and resistances to be more transparently and comprehensively factored into, or excluded from, policy-making.

Model

A “web of causality” has been used to explore entities, actions and consequences within the domain (McCollum 2007). This is apparently the only attempt to model the trade. While helpful, it is limited to a simple diagnosis of the underlying causes (hobbyist demand), and problem resolution focused solely on non-government organisation influences on knowledge and practises.

When analysing environmental indicators and constructing policy options, the DPSIR is used. This proposes that “drivers” lead to “pressures”, which affect the “state” of a system. Changes in “states” then have “impacts” and, consequently, a number of “responses” can be derived in order to tackle the problem at any of its links (Kristensen 2004). Human development needs can also be considered alongside environmental conservation opportunities (Svarstad et al. 2008). A comprehensive DPSIR framework covering the domain could be a useful contribution to policy-making and practice.

Analysis

Despite detailed analyses of some small subsections of the domain such as Indonesia (Reksodihardjo-Lilley and Lilley 2007) and post-capture culture (Bell et al. 2009), recent analyses of the whole domain have either focused on single strategies such as consumer advocacy (Livengood and Chapman 2010), or have been restricted to a minimalist expert consensus position (Tissot et al. 2010). This review is intended as a comprehensive, yet succinct, review of the domain, in the expectation that a comprehensive ontology and DPSIR framework will allow for better recommendations to emerge.

Conclusions

Little comprehensive or recent data are available on the scale of the tropical marine fish trade, with large-scale reviews relying on estimates. More has been described about the trade’s negative attributes than its positive ones. The trade’s structure and impacts are broadly known but not usefully collated. A number of solutions of varying utility have been attempted or proposed. The trade also has a number of helpful analogies from which lessons can be learned. But even without the questionable outcomes of MAC’s history, it is possible to imagine that it and the recently launched Aquaculture Stewardship Council share analogous vulnerabilities to MSC. These are related to their similar origins, structures and methodologies, if not to a common conceptual weakness associated with the wider eco-certification movement. The potential for these or other certification initiatives to benefit tropical reef sustainability, reef-using human communities, and reef fish welfare is by no means assured.

It is time to consolidate what is known in the field, and to analyse it with new methods, before making more policy decisions. With increasingly strongly contested assertions, potentially divergent objectives to the mainstream fair trade movement, and an uncertain future regarding the public perception of fish welfare (in the context of potentially under-utilised laws in the UK), the time is ripe, now that new tools are available.

References

- Agnew D., Grieve C., Orr P., Parkes G. and Barker N. 2006. Environmental benefits resulting from certification against MSC’s Principles and Criteria for Sustainable Fishing. London: MRAG UK Ltd and Marine Stewardship Council. Retrieved from Web 22 June 2010, http://www.msc.org/documents/environmental-benefits/MSC_Environmental_Benefits_Report_Phase1_FINAL_4Ma.pdf.

- Albins M.A. and Hixon M.A. 2008. Invasive Indo-Pacific lionfish *Pterois volitans* reduce recruitment of Atlantic coral-reef fishes. *Marine Ecology Progress Series* 367:233–238.
- Alencastro L.A., Degner R.L. and Larkin S.L. 2005. Hobbyists' preferences for marine ornamental fish: A discrete choice analysis of ecolabeling and selected product attributes. *SPC Live Reef Fish Information Bulletin* 15:19–22.
- Balmford A. and Whitten T. 2003. Who should pay for tropical conservation, and how could the costs be met? *Oryx* 37(02):238–250.
- Bell J.D., Clua E., Hair C.A., Galzin R. and Doherty P.J. 2009. The capture and culture of post-larval fish and invertebrates for the marine ornamental trade. *Reviews in Fisheries Science* 17(2):223.
- Bellamy J.-J. and Winsby M. 2008. Mid-term review of the IFC/GEF Project "Marine Aquarium Market Transformation Initiative (MAMTI)." Washington (DC): International Finance Corporation. Retrieved from Web 24 June 2010, <http://www.aquariumcouncil.org/pdf/MAMTI%20MTR.pdf>.
- Bicknell J.E. 2004. Sustainable, community-based aquarium fisheries in the north Rupununi, Guyana. *OFI (Ornamental Fish International) Journal* (44):22–24.
- Chao N.L. and Prang G. 1997. Project Piaba – Towards a sustainable ornamental fishery in the Amazon. *Aquarium Sciences and Conservation* 1(2):105–111.
- Cooper C. and Best B.A. 2009. International trade in coral reef species: Ecosystem impacts, management and policy options. In: *Making marine science matter*. International Marine Conservation Congress Annual Convention. Washington (DC). Retrieved from Web 17 November 2009, http://www2.cedarcrest.edu/imcc/Program_Abstracts/data/documents/s62214.pdf.
- Dickson M. 2010. Interview – Philip Smith, Aquaculture Stewardship Council. *Fish Farmer Magazine* 33(3):66–67.
- Dufour V. 1997. Pacific Island countries and the aquarium fish market. *SPC Live Reef Fish Information Bulletin* 2:6–11.
- EC-PREP (European Community's Poverty Reduction Effectiveness Programme) 2004. The Indonesian ornamental fish trade: Case studies and options for improving livelihoods while promoting sustainability in Banggai and Banuwangi. STREAM/EC-PREP. Retrieved from Web 30 November 2009, <http://aquacomm.fcla.edu/2247/>.
- Fairtrade Foundation 2008. Response to Adam Smith Institute report. Retrieved from Web 25 June 2010, http://www.fairtrade.org.uk/press_office/press_releases_and_statements/feb_2008/response_to_adam_smith_institute_report.aspx.
- Fenner R. 2008. *The conscientious marine aquarist – a commonsense handbook for successful saltwater hobbyists*, 2nd ed. Neptune City (NJ): TFH Publications.
- FLO (Fairtrade Labelling Organizations International) 2010. Why Fairtrade is unique. Retrieved from Web 25 June 2010, http://www.fairtrade.net/why_fairtrade_is_unique.html.
- Garshol L.M. 2007. Towards a methodology for developing topic maps ontologies. p. 20–31. In: *Proceedings of the 2nd international conference on Topic Maps research and applications*. Leipzig: Springer-Verlag.
- Gastner M.T. and Newman M.E.J. 2004. Diffusion-based method for producing density-equalizing maps. *Proceedings of the National Academy of Sciences of the United States of America* 101(20):7499–7504.
- Gerstner C.L., Ortega H., Sanchez H. and Graham D.I. 2006. Effects of the freshwater aquarium trade on wild fish populations in differentially fished areas of the Peruvian Amazon. *Journal of Fish Biology* 68(3):862–875.
- Glaser M., Baitoningsih W., Ferse S.C.A., Neil M. and Deswandi R. 2010. Whose sustainability? Top-down participation and emergent rules in marine protected area management in Indonesia. *Marine Policy* 34(6):1215–1225.
- Goyert W., Sagarin R. and Annala J. 2010. The promise and pitfalls of Marine Stewardship Council certification: Maine lobster as a case study. *Marine Policy* 34(5):1103–1109.
- Green E. 2003. International trade in marine aquarium species: Using the global marine aquarium database. p. 29–48. In: James C.L.B. and Cato C. (eds). *Marine ornamental species*. Ames, Iowa, USA: Iowa State Press.
- Grey M., Blais A.-M. and Vincent A.C.J. 2005. Magnitude and trends of marine fish curio imports to the USA. *Oryx* 39(04):413–420.
- Gulbrandsen L.H. 2009. The emergence and effectiveness of the Marine Stewardship Council. *Marine Policy* 33(4):654–660.
- Hayes T. 2008. Sustainable marine aquarium hobby. *Reef Ramblings*. Retrieved from Web 11 January 2010, <http://reeframblings.co.uk/?cat=14>.

- Hayes T. 2009. The growing imperative for the captive breeding of reef fishes. In: 12th National Aquarium Workshop programme. London: Horniman Museum.
- IATA (International Air Transport Association) 2010. Live Animals Regulations (LAR). Retrieved from Web 25 June 2010, <http://www.iata.org/ps/publications/Pages/live-animals.aspx>.
- ISO (International Organization for Standardization) 2003. ISO/IEC 13250:2003 – Information technology – SGML applications – Topic maps. Retrieved from Web 24 June 2010, http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=38068.
- Jones R.J. 1997. Effects of cyanide on coral. SPC Live Reef Fish Information Bulletin 3:3–8.
- Kingsford R.T., Watson J.E.M., Lundquist C.J., Venter O., Hughes L., Johnston E.L., Atherton J., Gawel M., Keith D.A., Mackey B.G., Morley C., Possingham H.P., Raynor B., Recher H.F. and Wilson K.A. 2009. Major conservation policy issues for biodiversity in Oceania. Conservation Biology 23:834–840.
- Koldeway H. and Zimmerman B. 2007. Sustainable acquisition in aquariums. EAZA News 60:30–32.
- Kolm N. and Berglund A. 2003. Wild populations of a reef fish suffer from the “nondestructive” aquarium trade fishery. Conservation Biology 17(3):910–914.
- Kristensen P. 2004. The DPSIR Framework. p. 1–10. In: Workshop on a comprehensive / detailed assessment of the vulnerability of water resources to environmental change in Africa using river basin approach. UNEP Headquarters, Nairobi, Kenya. Retrieved from Web 18 January 2010, http://enviro.lclark.edu:8002/rid=1145949501662_742777852_522/DPSIR%20Overview.pdf.
- Lecchini D., Polti S., Nakamura Y., Mosconi P., Tsuchiya M., Remoissenet G. and Planes S. 2006. New perspectives on aquarium fish trade. Fisheries Science 72(1):40–47.
- Lieberman S. and Field J. 2001. Global solutions to global trade impacts? p. 19–24. In: Best B. and Bornbusch A. (eds). Global trade and consumer choices: Coral reefs in crisis. Papers presented at a symposium held at the 2001 annual meeting of the American Association for the Advancement of Science. Washington D.C. USA: American Association for the Advancement of Science.
- Livengood E.J. and Chapman F.A. 2010. The ornamental fish trade: An introduction with perspectives for responsible aquarium fish ownership. University of Florida. Retrieved from Web 30 June 2010, <http://edis.ifas.ufl.edu/fa124>.
- Mainent D. 2007. MAC interim Director: The industry behind the hobby – page 2. Retrieved from Web 11 January 2010, <http://www.reefs.org/forums/topic108485-20.html>.
- Mainent D. 2009. Announcing the new MAC Licensed Retailer Program. Retrieved from Web 11 January 2010, <http://www.qualitymarine.com/Documents/D8C1891C-2D19-4967-BDDC-1506514B7A7F.pdf>.
- McAllister D.E., Caho N.L. and Shih C.-T. 1999. Cyanide fisheries: Where did they start? SPC Live Reef Fish Information Bulletin 5:18–21.
- McCollum B.A. 2007. Consumer perspectives on the “web of causality” within the marine aquarium fish trade. SPC Live Reef Fish Information Bulletin 17:20–30.
- MOFIB (Marine Ornamental Fish and Invert Breeders Association) 2010. View forum – Fish. Retrieved from Web 24 June 2010, <http://www.marinebreeder.org/phpbb/viewforum.php?f=133&sid=61c83809c194c91584d601b26ecc7b7>.
- Muldoon G.J. and Johnston B. 2006. Market chain analysis for the trade in live reef food fish. In: Australian Agricultural and Resource Economics Society Conference 2006. Sydney: Australian Agricultural and Resource Economics Society. Retrieved from Web 23 June 2010, http://www.aares.info/files/2006_muldoon.pdf.
- Murray J.M. 2010. Regeneration and reproduction in *Sabellaria pavonina* (Savigny): Developing a novel method to culture marine ornamental sabellids. Portsmouth, Hampshire, UK: University of Portsmouth.
- NRMMC 2006. A strategic approach to the management of ornamental fish in Australia. Canberra: Natural Resource Management Ministerial Council, Commonwealth of Australia.
- OATA (Ornamental Aquatic Trade Association) 2000. Code of conduct. Retrieved from Web 24 June 2010, <http://www.ornamentalfish.org/common/acrobat/codeofconduct.pdf>.
- Pancevski B. 2008. New Swiss law protects rights of “social” animals. The Times (UK). Retrieved from Web 25 June 2010, <http://www.times-online.co.uk/tol/news/world/europe/article3818457.ece>.

- Pang B. and Lee L. 2008. Opinion mining and sentiment analysis. *Foundation and Trends in Information Retrieval* 2(1-2):1-135.
- Pepper S. 2002. The TAO of topic maps. Retrieved from Web 17 May 2010, <http://www.ontopia.net/topicmaps/materials/tao.html>.
- Pet J.S. and Djohani R.H. 1998. Combating destructive fishing practices in Komodo National Park: Ban the hookah compressor! *SPC Live Reef Fish Information Bulletin* 4:17-28.
- Pomeroy R.S., Parks J.E. and Balboa C.M. 2006. Farming the reef: Is aquaculture a solution for reducing fishing pressure on coral reefs? *Marine Policy* 30(2):111-130.
- Ponte S. 2008. Greener than thou: The political economy of fish ecolabeling and its local manifestations in South Africa. *World Development* 36(1):159-175.
- Reksodihardjo-Lilley G. and Lilley R. 2007. Towards a sustainable marine aquarium trade: An Indonesian perspective. *SPC Live Reef Fish Information Bulletin* 17:11-19.
- Rhyne A., Rotjan R., Bruckner A. and Tlusty M. 2009. Crawling to collapse: Ecologically unsound ornamental invertebrate fisheries. *PLoS ONE* 4(12):e8413.
- Roelofs A. and Silcock R. 2008. A sustainability assessment of marine fish species collected in the Queensland marine aquarium trade, Brisbane. Australia Department of Primary Industries and Fisheries.
- Rubec P.J. and Cruz F.P. 2005. Monitoring the chain of custody to reduce delayed mortality of net-caught fish in the aquarium trade. *SPC Live Reef Fish Information Bulletin* 13:13-23.
- Saxby A., Adams L., Snellgrove D., Wilson R. W. and Sloman K. A. 2010. The effect of group size on the behaviour and welfare of four fish species commonly kept in home aquaria. *Applied Animal Behaviour Science* 125(3-4):195-205.
- Scales H., Balmford A. and Manica A. 2007. Monitoring the live reef food fish trade: Lessons learned from local and global perspectives. *SPC Live Reef Fish Information Bulletin* 17:36-42.
- Schmidt C. and Kunzmann A. 2005. Post-harvest mortality in the marine aquarium trade: A case study of an Indonesian export facility. *SPC Live Reef Fish Information Bulletin* 13:3-12.
- Shuman C. S., Hodgson G. and Ambrose R.F. 2004. Managing the marine aquarium trade: Is eco-certification the answer? *Environmental Conservation* 31(04):339-348.
- Smith K.F., Behrens M.D., Max L.M. and Daszak P. 2008. U.S. drowning in unidentified fishes: Scope, implications, and regulation of live fish import. *Conservation Letters* 1:103-109.
- Svarstad H., Petersen L.K., Rothman D., Siepel H. and Wätzold F. 2008. Discursive biases of the environmental research framework DPSIR. *Land Use Policy* 25(1):116-125.
- Swiss Confederation 2008. SR 455.1 Tierschutzverordnung vom 23. April 2008 (TSchV). Retrieved from Web 25 June 2010, http://www.admin.ch/ch/d/sr/c455_1.html.
- Taber M. 2008. A sustainable and ethical marine aquarium trade. *Reefs UK*. Retrieved from Web 28 April 2010, <http://www.takelifeeasy.com/reefsuk/proposal.pdf>.
- Teitelbaum A., Yeeting B., Kinch J. and Ponia B. 2010. Aquarium trade in the Pacific. *SPC Live Reef Fish Information Bulletin* 19:3-6.
- Thorburn C.C. 2003. Fatal adaptation: Cyanide fishing in the Kei Islands, Southeast Maluku. *SPC Live Reef Fish Information Bulletin* 11:5-12.
- Tissot B.N. 1999. Adaptive management of aquariumfish collecting in Hawaii. *SPC Live Reef Fish Information Bulletin* 6:16-19.
- Tissot B.N., Best B. A., Borneman E. H., Bruckner A. W., Cooper C. H., D'Agnes H., Fitzgerald T. P., Leland A., Lieberman S., Mathews Amos A., Sumaila R., Telecky T. M., McGilvray F., Plankis B. J., Rhyne A. L., Robert G. G., Starkhouse B. and Stevenson T. C. 2010. How U.S. ocean policy and market power can reform the coral reef wildlife trade. *Marine Policy* 34(6):1385-1388.
- Tlusty M., Dowd S. and Ortiz von Halle B. 2006. Yes fish need to be certified – a reply to Watson. *OFI Journal* 51:19-22.
- TRAFFIC Europe 2009. International and EU Legislation. Retrieved from Web 25 June 2010, http://www.eu-wildlifetrade.org/pdf/en/1_international_legislation_en.pdf.
- UNEP-WCMC (United Nations Environment Programme – World Conservation Monitoring Centre) 2008. Consultation Process on Monitoring of International Trade in Ornamental Fish. European Commission. Retrieved from Web 3 March 2010, <http://www.unep-wcmc.org/species/reports/Consultation%20Paper%20-%20Final.doc.doc>.
- United Kingdom Parliament. 1981. Zoo Licensing Act 1981. Retrieved from Web 25 June 2010, http://www.opsi.gov.uk/RevisedStatutes/Acts/ukpga/1981/cukpga_19810037_en_1.

- United Kingdom Parliament. 1983. Pet Animals Act 1951 (Amendment) Act 1983. Retrieved from Web 25 June 2010, http://www.opsi.gov.uk/RevisedStatutes/Acts/ukpga/1983/cukpga_19830026_en_1.
- United Kingdom Parliament. 2006. Animal Welfare Act 2006. Retrieved from Web 25 June 2010, http://www.opsi.gov.uk/acts/acts2006/ukpga_20060045_en_1.
- Vagelli A.A. 2008. The unfortunate journey of *Pterapogon kauderni*: A remarkable apogonid endangered by the international ornamental fish trade, and its case in CITES. SPC Live Reef Fish Information Bulletin 18:17-28.
- Vincent A.C.J. 2008. Reconciling fisheries with conservation on coral reefs: The world as an onion. p. 1435-1467. In: Nielsen J. et al. (eds). Reconciling fisheries with conservation: Proceedings of the Fourth World Fisheries Congress. Symposia. American Fisheries Society.
- Wabnitz C., Taylor M., Green E. and Razak T. 2003. From ocean to aquarium. Cambridge: UNEP World Conservation Monitoring Centre.
- Whittington R.J. and Chong R. 2007. Global trade in ornamental fish from an Australian perspective: The case for revised import risk analysis and management strategies. Preventive Veterinary Medicine 81(1-3):92-116.
- Wood E.M. 2001. Collection of coral reef fish for aquaria: Global trade conservation issues and management strategies. UK: Marine Conservation Society.
- Wood E. and Dakin N. 2003. The responsible marine aquarist. Ross-on-Wye: Marine Conservation Society.
- Wu L. 2009. Cute “Finding Nemo” clownfish could be rising star of Taiwan’s aquaculture sector. The China Post. Retrieved from Web 23 November 2009, <http://www.chinapost.com.tw/taiwan/national/national-news/2009/07/02/214558/p1/Cute-%27Finding.htm>.
- Zajicek P., Hardin S. and Watson C. 2009. A Florida marine ornamental pathway risk analysis. Reviews in Fisheries Science 17(2):156.