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Marine ornamental species culture: From the past to "Finding Dory"

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ABSTRACT

The present article revises the major topics related to fish and coral reproduction. In particular after a short review of the ornamental trade and the destructive fishing methods that are still used in some areas, the present review revises the principal modes of fish and coral reproduction introducing the main critical bottlenecks in their captive propagation. Regarding fish these include sexing the fish, pair forming, the embryo development, the hatching process and of course the transition from an endogenous to an exogenous feeding by the larvae. As concerns corals, great attention is given to the main modes of reproduction as well as to nutrition and lightening.

1. Marine ornamentals trade

Coral reefs cover a very small portion of the marine environment but they are considered as the most biodiversified ecosystems on Earth (Olivotto et al., 2006a). They support several species of fish and of reef building corals as well as a great number of invertebrates. At date, there are several negative pressures on coral reefs that include the climate change, the increasing trend of the temperature that might cause coral bleaching, the unsustainable fishing, that caused a serious decline of fish stocks and the nutrient enrichment of coastal waters, due to human wastes and agriculture runoff (Olivotto et al., 2011b). Among these the aquarium trade can also have a negative impact on the coral reef ecosystem.

If we consider modern reef tanks and we virtually imagine to dive in these tanks, we can really observe a small portion of coral reef within the tank walls. Nowadays, tanks host not only fish but also a great variety of reef building corals and other invertebrates. However, the question that still remains is: from where do these fish and invertebrates come from?

Unlike freshwater aquaria species, where more than 90% of the species are currently farmed, most of marine aquaria are still stocked from wild caught species (Green, 2003; Wabnitz et al., 2003; Olivotto et al., 2011b). The great majority of the animals used in the aquarium trade are collected from the wild using environmental friendly collecting methods such as nets and traps, but others are still collected using methods that harm the delicate marine ecosystems. Among these the use of cyanide and dynamite are the more destructive ones (Wabnitz et al., 2003).

Cyanide is used as an anesthetic and is spread by divers on coral reefs. This method is non selective and kills not only the fish but also invertebrates and many other organisms including larvae, bacteria and plankton (Barber and Pratt, 1998). Dynamite, which is a common practice for food fishing, is based on the use of small artisanal bombs that are built using empty glass bottles filled with fertilizers and sand. By the blast, this extremely non selective fishing method, kills fishes and invertebrates and destroys the physical structure of the reef making it more difficult for new planulae to settle. As a consequence the reef recovery is delayed in a severe way.

Also coral collection can harm the reef ecosystem (Ellis, 1999; Calfo, 2007). Coral collection for the aquarium trade is mainly based on the collection of coral fragments: divers often use hammers and other equipment to extract coral fragments; however they do not really take care of saving the reef. As a consequence, the use of these destructive fishing methods causes the destruction of most corals and coral reef physical structure with a consequent decline in fish populations and loss of biodiversity.

After collection the animals are usually transferred to an exporter facility where they should undergo quarantine and acclimation to captive conditions. Nowadays, the use of jet airplanes allows to

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ship live animals from coral reefs to almost anywhere in the world. Typically, they are packed for shipping so that they can withstand several hours of transit time. Corals and fish are first shipped to a wholesale facility, where they are either directly sold, distributed in the proximity of the wholesale facility, or transhipped to their next destination. During transport, the animals can be subject to large temperature oscillation and prolonged confinement in the dark. In addition, during the shipment, unnatural or inadequate conditions, with respect to water flow, pH, nutrition, and light, often occur causing severe stress response in the organisms. It is thus estimated that from oceans to aquaria about 60–70% on the traded animals die during capture, shipment and handling because of the use of chemicals during collection, poor handling practice and disease (Wabnitz et al., 2003).

The aquarium trade is also very often a "victim of fashion". In 2003, Disney and Pixar released their hit movie, "Finding Nemo". The primary goal of the movie was to portray the message that fish are better off left in the wild, however, the final result was that most of the people did not realize, the responsibility, the cost and maintenance, and the ethical responsibility to care for a living creature such as *Amphiprion ocellaris*.

From here the importance of studying the reproduction of some of the species most commonly used in the aquarium trade in order to produce an alternate supply of fish and to have a better knowledge about their biology (Olivotto et al., 2003, 2004, 2006a,b). These information together are essential for a better management of natural stocks and for understanding responses of human impacts (Tlusty, 2002).

2. Fish

At date there are still numerous critical factors in the early life history of fish where deficiencies may represent a limiting factor in captive propagation (Holt, 2000, 2003; Wittenrich, 2007; Moorhead and Zeng, 2010; Olivotto et al., 2011b). For example to breed and culture a certain fish species we need to be able to sex the fish, to induce spawning, to have a proper embryo development, to hatch the embryos and of course to promote the transition from an endogenous to an exogenous feeding by the larvae (Thresher, 1984; Holt and Riley, 2001; Holt, 2011). The life history of most marine ornamental fish is made of different biological/ecological phases: (a) the adults that are sexually mature and produce eggs and sperm; (b) the embryos that develop for a species specific time protected by the chorion membrane and rely on yolk reserves; (c) the hatching that consists in breaking the chorion membrane and reaching an independent life by the larvae (Olivotto and Carnevali, 2004); (d) the larvae that usually spend a period in the plankton feeding on a great variety of microorganism; (e) and the juveniles that after metamorphosis settle down on the reef and will secondly reach sexual maturity closing the cycle. In order to cultivate marine ornamentals we need to understand and study on all these stages (Olivotto et al., 2009).

The reproductive strategies developed by fish are extremely diverse and a deeper knowledge about this topic is a crucial factor in determining the success of captive propagation.The two dominant modes of egg dispersal among marine fish are the demersal and pelagic spawners (Setu and Kumar, 2010; Olivotto et al., 2011a,b).

Demersal spawners produce eggs that are attached to a solid surface or laid as egg balls. Spawning occurs in the morning/afternoon and the average number of eggs/clutch is 100–1000. All the demersal species display parental care until the embryos hatch. Typical examples are damselfish, clownfishes, dottybacks, gobies and blennies (Brons, 1996; Moe, 1997; Asoh and Yoshikawa, 2002; Olivotto et al., 2005; Avella et al., 2007; Meirelles et al., 2009; Olivotto et al., 2011a,b; Setu et al., 2010; Madhu and Madhu, 2014;.

Pelagic spawners usually display complex courtship, eggs and sperm are released in the water column, eggs are smaller and produced in greater number (300–1,000,000) if compared to demersal spawners, and they usually spawn at dusk. This is actually a transitional period on the reef: diurnal predators are seeking refuge on the reef, nocturnal ones are not fully active and predatory pressures are thus lower at this time.Spawning starts near the bottom and ends with an ascent movement close to the water surface where the gametes are released above the reef structure to reduce predatory activity of planktivore species and to assist the eggs in their up-ward migration. Typical examples of pelagic spawners are angelfishes, wrasses, surgeonfish and snappers (Holt and Riley, 2001; Olivotto et al., 2006a; Leu et al., 2007; Baensch and Tamaru, 2009; Leu et al., 2009; Bushnell et al., 2010; Leu et al., 2010; Laidley et al., 2011; Leu et al., 2012; Callan et al., 2013; Chen et al., 2013).

Both for demersal or pelagic spawners the fish have to develop the reproductive competences that include the integration of internal and external cues (Thresher, 1984; Olivotto et al., 2011b). Of great interest are the metabolic cues (size and energetic status of the fish), the environmental cues (proper environmental conditions for offspring survival) and the social cues (presence of both female and male fish).

Regarding sexuality, fish show a great plasticity (Thresher, 1984; Wittenrich, 2007). There are in fact gonochoristic species that are born as males or as females and are not able to change their sex during the life, and the hermaphroditic ones. Some are simultaneous and have both female and male gonads (i.e. Serranidae) but usually avoid self-fertilization, while others are sequential.

Most of the fish species are sequential hermaphrodites (Moe, 1997; Messmer at al., 2005; Munday et al., 2010) and this means that a same individual can change sex during the life time. Some species are protandrous changing sex from male to female (Olivotto et al., 2008a,b). A typical example is the clownfish society: the biggest fish is the dominant female, which was originally a male, while the second biggest is the sexual active male. All the other fishes that are part of the social structure are immature males. Some other species are protogynous and this means that the sex can change from female to male. Typical examples are dottybacks and angelfishes (Brons, 1996; Moe, 1997; Holt and Riley, 2001; Laidley et al., 2004).

Environmental cues also play a key role in the development of the reproductive competences in fish (Holt and Riley, 2001). In fact, environmental conditions should be optimal to guarantee reproductive success and offspring survival. At this regard the hypothala mus–pituitary–gonadal axis plays a key role in translating external cues such as photoperiod, food availability and temperature in hormonal signals that are able to promote ovulation and spermiation in fish. Several studies have shown the importance of temperature and light/dark regimes and fish reproduction, and in general for ornamentals, there is a strong positive correlation between high temperatures and long days and number of eggs produced (Olivotto et al., 2011a). As a consequence spawning events are reduced in November–anuary in the Northern hemisphere and in June–August in the Southern one.

Technology is thus essential in manipulating these parameters in captivity, and in the reproduction of marine ornamentals a key role is played by heaters, chillers, lights and light timers. By controlling these parameters we can naturally induce spawning in many fish species by mimicking natural environmental conditions (Holt and Riley, 2001; Olivotto et al., 2003, 2006a, 2008c). For demersal spawners it is sufficient to provide the fish with high (>27 °C) temperatures and long days (14 h light) (Olivotto et al., 2009),