A review of the movements of fish held in captivity in the Reunion Island Aquarium over a five-year period

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Introduction

For about 20 years, the marine aquarium fish trade has been showing continuous growth and now involves major movements of wild reef fish all over the world (Dufour 1998; Wood 2001; Sadovy and Vincent 2002; Sadovy 2003; Wabnitz et al. 2003). Also, the number of public aquaria displaying coral reef organisms is constantly expanding, while the size of display tanks is steadily increasing. To remain attractive to the public, aquarium managers find they must adopt innovative approaches, and display ever bigger and scarcer living organisms. There is no accurate measure of the quantity of marine fish caught for such purposes. Given this context, there seemed to be merit in publishing a review of fish movements into and out of Reunion Island Aquarium (as recorded over a five-year period of aquarium operations), as well as an assessment of the capacity of the various fish families to adapt to captivity under the conditions found at the aquarium.

Materials and methods

Reunion Island Aquarium is situated on the west coast of the island of Réunion, which lies in the western Indian Ocean. This private venture displays the marine flora and fauna of Réunion in a group of 14 tanks varying in volume from 1 to 320 cubic meters (m^3). The total volume of seawater in all the tanks is 700 m^3. This water is pumped in directly from the natural environment and treated in a 100 m^3 buffer tank where it undergoes decantation, mechanical filtering, cooling (the temperature is regulated at 26 °C) and oxygenation.

All fish in Reunion Island Aquarium come from the waters around the island and all are captured at depths between 0 and 50 meters. Eighty per cent of them are caught by the aquarium's divers and biologists, while 20% are captured by professional fishers. Various techniques are used for capturing the fish: nets, daytime and night-time dives, anaesthetizing products, basket traps, bottom fishing, and scoop nets. These highly selective capture activities are only carried out three to four times monthly and concern only two to three specimens on average per operation.

During the transport phase, which lasts less than an hour, the fish are placed in tanks with water agitation and aeration systems. They are then kept in quarantine for two to eight weeks, depending on their capacity to adapt. This obligatory stage allows parasites to be removed from the fish, allows fish to become accustomed to a different diet from that of their natural environment, and helps mitigate the stress associated with captivity. The next step is to place the fish in the display tanks. Depending on their size and liveliness, they may need to be anaesthetized for this step.

Fish movements are recorded in a register of "arrivals and departures of animals of non-domestic species held in captivity" and another known as the "register of movements of animals held in captivity".[3] This accounting system makes it possible to monitor the number of incoming (caught, donated, born) and outgoing (died, reintroduced, donated) specimens. In this study, we have limited our assessment to captured fish ("arrivals") and mortalities ("departures"). In other words, the study included only individual fish that were captured and at the end of the five-year study period either remained in the aquarium or had died. We have looked at all fish families over the five-year period.

We sought to identify the families that best adapted to captivity under the aquarium's conditions and fish management practices. A "success rate", expressed in terms of the number of fish present at the end of the five-year study period as a proportion of the total number of arrivals during that period, was computed for each family. The results were divided into three categories: families offering "easy" management (success rate greater than 50%), those "difficult" to manage

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(success rate between 26 and 50%) and those with "complex" management needs (success rate between 0 and 25%).

We also recorded the mean "length of stay" for each family; that is, the mean length of time spent by all specimens from a given family in the aquarium from arrival to departure. This value can help us gain a better understanding of the capacity of various families to adapt to the aquarium's conditions.

Results

Over five years, 990 fish from 43 families were caught (Table 1). The best represented families were Serranidae with 10.4% of arrivals, followed by Acanthuridae (7.2%), Labridae (7.1%), Pomacentridae (7.1%) and Chaetodontidae (6.8%). In contrast, others such as Sphyrnidae were represented by a single specimen only. Of these 990 fish, 451, or 45.5% of the total number of arrivals, were subsequently recorded as departures in the register. Syngnathidae (10.4%), Chaetodontidae (9.7%), Apogonidae (8.2%), Labridae (6.7%) and Holocentridae (6.4%) were the families with the most departures.

The mean length of stay for all families combined was 25 months. Seventeen families stayed for more than 30 months out of the 60-month study period. The best results were obtained with the families Pomacentridae (56 months), Serranidae (53 months), Carangidae (52 months) and Sphyraenidae (51 months). In contrast, some families could only be kept for a few months, such as Pempheridae (3 months), Monacanthidae (5 months), Plotosidae (5 months) and Diodontidae (5 months).

A detailed examination of arrivals and departures on an annual basis shows that 518 specimens were caught during the first year, when the aquarium was opened, which represents more than half of the total arrivals. Over the following four years departures stabilized at a mean of about 117 fish per year. The total stock size showed an upward trend, increasing from 370 at the end of 2000 to 539 in 2005, while the annual number of departures as compared to arrivals fell, with 28.6% of the fish departing in 2000 compared to 12.1% in 2004: that is, an annual mean rate of 17.2% (Table 2).

Examination of success rates for each family represented in the aquarium's tanks shows that 15 families can be considered as "easy" to handle, including the families Pomacentridae (90%), Kuhliidae (86.7%), Monodactylidae (84.6%), Serranidae (84.5%) and Carangidae (82.4%); 16 families are "difficult", particularly the families Mullidae (26.3%), Syngnathidae (27.7%), Caesionidae (33.3%), Haemulidae (33.3%) and Siganidae (33.3%); and, 12 families are "complex", including Sphyrnidae (0%), Dactylopteridae (0%), Priacanthidae (0%), Pempheridae (0%) and Diotontidae (0%) (Fig. 1).

Table 1. Arrivals and departures (in number of specimens) and mean length of stay (in months) from a study of 43 families of reef fish over a 60-month period at Reunion Island Aquarium.

Family	Arrivals	Departures	Mean length of stay
Carcharhinidae	7	4	12
Sphyrnidae	1	1	18
Dasyatidae	5	4	24
Muraenidae	5	1	48
Plotosidae	11	7	5
Antennaridae	5	3	35
Holocentridae	46	29	26
Aulostomidae	5	4	23
Syngnathidae	65	47	13
Dactylopteridae	2	2	14
Scorpaenidae	39	21	47
Serranidae	103	16	53
Cirrhitidae	12	6	27
Apogonidae	47	37	14
Kuhliidae	45	6	36
Priacanthidae	7	7	6
Malacanthidae	5	3	13
Carangidae	17	3	52
Lutjanidae	43	25	34
Caesionidae	6	4	38
Haemulidae	3	2	16
Lethrinidae	23	21	10
Mullidae	19	14	19
Pempheridae	8	8	3
Ephippidae	10	5	22
Monodactylidae	26	4	49
Chaetodontidae	67	44	13
Pomacanthidae	28	6	33
Pomacentridae	70	7	56
Labridae	70	30	32
Sphyraenidae	3	1	51
Blennidae	21	4	35
Microdesmidae	8	5	11
Gobiidae	11	3	15
Zanclidae	11	9	10
Acanthuridae	71	18	41
Siganidae	3	2	14
Bothidae	5	2	38
Balistidae	14	4	41
Monacanthidae	14	13	5
Ostracidae	11	9	7
Tetraodontidae	14	6	25
Diodontidae	4	4	5
Total	990	451	

Table 2. Initial stock of fish, number of arrivals, number of departures and annual summary expressed as the number of departures as a proportion of the sum of the year's initial stock and arrivals.

	2000	2001	2002	2003	2004	2005
Initial stock	-	370	426	410	450	539
Arrivals	518	120	85	104	163	-
Departures	148	64	101	64	74	-
Summary (%)	28.6	13.1	19.8	12.4	12.1	-

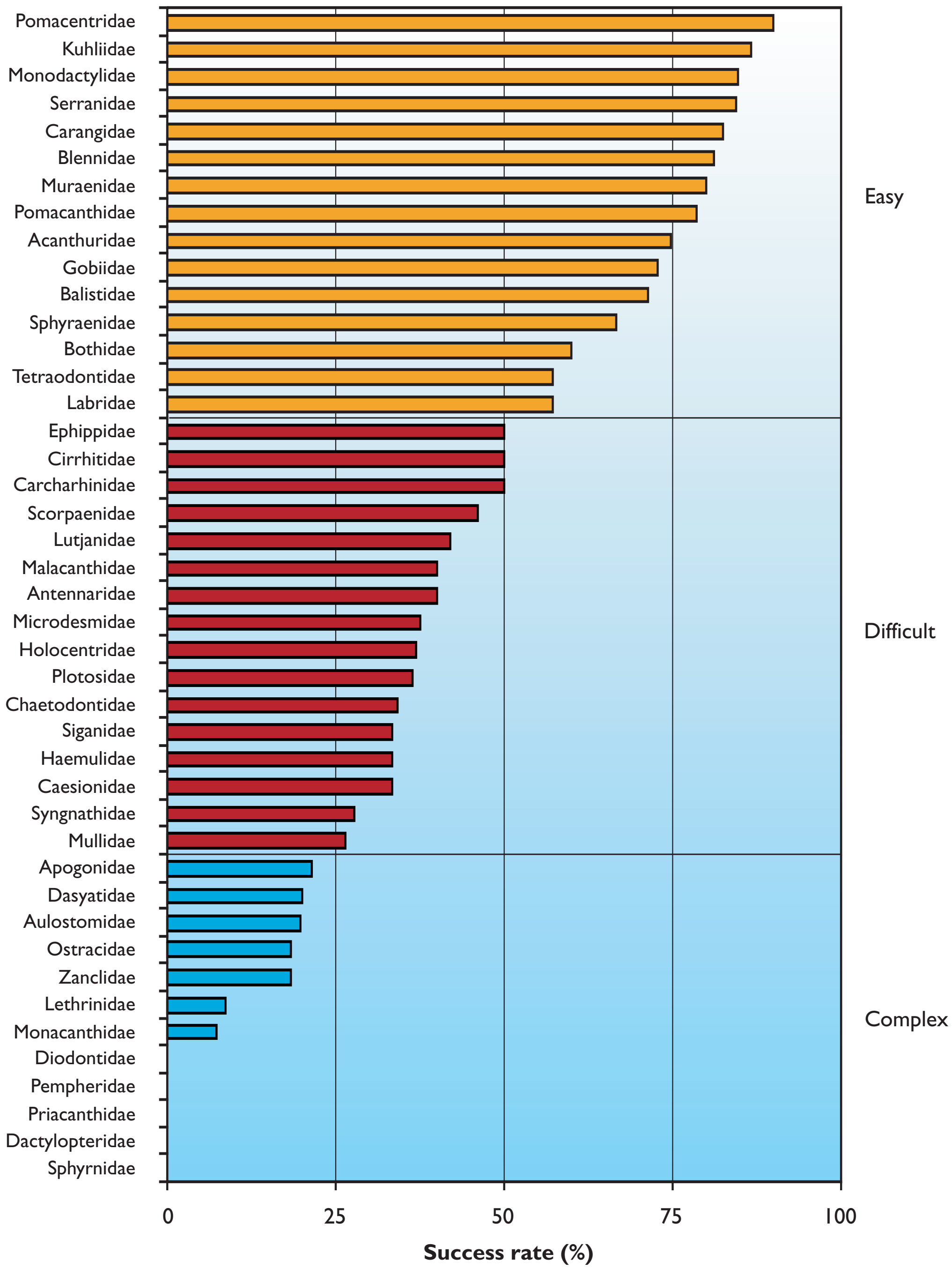

Figure 1. Success rate (expressed as the number of fish present at the end of the five-year study period as a percentage of the number of arrivals during that period), by family.

Discussion

It is difficult to generalize from these results because the aquarium's conditions and management practices are specific and not necessarily easy to reproduce elsewhere. In addition, with some families, only one or two specimens could be reared and the success or failure of their time in captivity is therefore not significant, even if their length of stay can yield information for the family. Many factors need to be taken into consideration and sometimes a detail about the capture, transport, diet, or introduction of a fish, or a change in a technical factor, can modify the balance of a population and make the management of a species a success or failure. Five years of experience have allowed us to better understand our stock's needs and consistently improve our success rates.

Of the 43 families we have handled, Pomacentridae seem the best suited to life in the aquarium. We find it easy to manage *Abudefduf vaigiensis*, *A. sexfasciatus*, *A. margariteus*, *A. sordidus*, *A. sparoides*, *Amphiprion chrysogaster*, *Chromis viridis*, *C. nigrura*, *C. chrysura*, *Dascyllus aruanus*, *D. carneus*, *Stegastes pelicieri* and *Pomachromis richardsoni*. We have more difficulties with *Dascyllus trimaculatus,* which is often attacked by parasitic protozooans. *Pomacentrus caeruleus* is easy to handle but readily loses its colouring in captivity.

The families Kuhliidae (*Kuhlia mugil* and *K. marginata*) and Monodactylidae (*Monodactylus argenteus*) pose no particular problem.

Serranidae such as *Pseudanthias evansi*, *P. squamipinnis*, *P. cooperi*, *Gracila albomarginata*, *Cephalopholis argus*, *C. urodeta*, *C. sonnerati*, *Epinephelus fasciatus, E. faveatus, E. flavocaeruleus*, *E. longispinis*, *E. merra*, *E. multinotatus*, *E. hexgonatus*, *E. radiatus*, *Variola louti* and *Grammistes sexlineatus* adapt easily to our conditions; the only difficulties occurred with *Pogonoperca punctata*.

Carangidae such as *Caranx ignobilis, C. melampygus*, *C. sexfasciatus*, *C. papuensis* and *Carangoides orthogrammus* also adapt but need large tank volumes from early in their stay; only *Trachinotus bailloni* and *Seriola rivoliana* pose parasite-related problems.

Blennidae, *Cirripectes polyzona* and *Ecsenius midas* in particular, are easy to manage.

Muraenidae seem fairly hardy and we put *Gymnothorax undulatus*, *G. flavimarginatus* and *Siderea grisea* together in the same tank.

Pomacanthidae (*Pomacanthus imperator*, *Centropyge acanthops* and *C. bispinosus*), which are often viewed as difficult to manage, also adapt easily to our conditions, except *Apolemichthys trimaculatus*, which is more fragile.

Similarly, Acanthuridae (*Zebrasoma velifer*, *Z. scopas*, *Z. gemmatum*, *Paracanthurus hepatus*, *Acanthurus dussumieri*, *A. mata*, *A. xanthopterus*, *A. tennenti*, *A. nigrofuscus*, *A. nigricauda*, *Ctenochaetus striatus*, *Naso lituratus*, *N. vlamingi*, *N unicornis*, *N. brevirostris*, *N. brachycentron* and *N. hexacanthus*), which have a reputation of being difficult, progress very well in our tanks. Some difficulties have been encountered with *Acanthurus guttatus*, *A. lineatus*, *A. triostegus* and *A. polyzona*.

The management of Gobiidae such as *Valencienna strigata, Gnatholepis* sp., *Fusigobius* sp. and *Asterropteryx semipunctatus* remains easy.

Balistidae (*Odonus niger*, *Balistoides conspicillum*, *Pseudobalistes fuscus*, *Abalistes stellatus*, *Rhinecanthus aculeatus* and *R. rectangulus*) are generally very hardy, but some difficulties have been recorded with *Xanthichthys auromarginatus*, *Sufflamen chrysopterus* and *S. bursa*.

Sphyraenidae, particularly *Sphyraena barracuda,* adapt very well and we have kept a male and a female for the past four years.

Bothidae, particularly *Bothus mancus*, are problem-free, although weaning onto inert food can take a very long time.

Tetraodontidae such as *Canthigaster valentini*, *C. janthinoptera*, *C. smithae*, *Arothron nigropunctatus*, *A. hispidus* and *A. immaculatus* are easy to handle, but problems of interspecific territoriality within this family have caused losses in *Arothron stellatus* and *A. meleagris*.

Labridae are the most diversified and we display to the public *Bodianus anthioides*, *B. axillaris, Cheilinus trilobatus*, *Epibulus insidiator*, *Novaculichthys taeniourus*, *Anampses meleagrides*, *Anampses lineatus*, *Coris aygula*, *C. africana*, *Halichoeres hortulanus*, *H. marginatus*, *H. cosmetus*, *Gomphosus caeruleus*, *Stethojulis albovittata*, *Thalassoma genivittatum*, *T. hardwicke*, *T. mascarenum*, *T. purpureum*, *T. trilobatum*, *Labroides bicolor* and *L. dimidiatus*; only a few species like *Bodianus diana*, *B. bilunulatus*, *B. macrourus*, *Oxycheilinus bimaculatus*, *Pseudocheilinus hextaenia*, *Anampses caeruleopunctatus*, *Halichoeres scapularis*, *H. nebulosus* and *Hologymnosus doliatus* have proved demanding.

Of the difficult families, Cirrhitidae, including *Paracirrhites arcatus*, *P. forsteri*, *Cirrhitops fasciatus*, *Cyprinocirrhites polyactis* and especially *Cirrhitus* *pinnulatus*, are very demanding in terms of diet and require a tank all to themselves.

Carcharhinidae are found in every aquarium, but remain difficult where some species are concerned. Our collection contains *Carcharinus albimarginatus,* which is the most common coastal shark in Réunion, but only young specimens less than 1.5 m in length can be handled. Each year, we reintroduce into the wild all the specimens that have outgrown our capacity and replace them with smaller individuals.

Scorpaenidae are relatively easy to handle, especially *Pterois miles*, *Synanceia verrucosa*, *Scorpaenopsis diabolus*, *S. oxycephala*, *Taenianotus triacanthus*, *Dendrochirus biocellatus*, *D. zebra* and, to a lesser extent, *Pterois antennata*. The losses we recorded in this family were due to an over-rich diet.

Lutjanidae such as *Aprion virescens*, *Lutjanus kasmira*, *L. fulvus* and *L. argentimaculatus* are hardy and adapt to captivity easily, but are aggressive and territorial. We lost more than 50% of these fish because of technical mishaps during the first year of operations.

With Malacanthidae, only *Malacanthus brevirostris* underwent extended trials, which finally led to a successful conclusion and the survival of a couple for more than 12 months at the time of this writing. *Malacanthus latovittatus* seems easier to rear but it is unusual and difficult to catch.

The Antennariideae (*Antennarius commersonii, A. striatus* and *Histrio histrio*) demand a great deal of attention because of chronic parasitic diseases.

Microdesmidae, with *Nemateleotris magnifica,* are challenging and do not adapt well to a tank in which various families are mixed together; *Ptereleotris evides* performs better in the same tank.

With Holocentridae (*Myripristis berndti*, *M. murdjan*, *Sargocentron diadema* and *S. spiniferum*), the most frequent problems were with exopthalmus (bulging of the eye).

With Chaetodontidae, a difficult family to manage, we only work with species offering broad dietary habits such as *Chaetodon melannotus*, *C. vagabundus*, *C. auriga*, *C. madagaskariensis*, *C. kleinii*, *C. guttatissimus*, *Hemitaurichthys zoster*, *Forcipiger longirostris*, *Heniochus acuminatus* and *H. monoceros*; only *Chaetodon lunula* regularly develops parasitic diseases.

Haemulidae such as *Plectorhinchus picus* are difficult, although *P. gibbosus* is easy to handle.

With Caesionidae, *Pterocaesio tile* and *Caesio teres* have been managed with a few difficulties, especially just after capture.

With regard to Syngnathidae, species such as *Corythoichthys flavofasciatus*, *C. schultzi* and *Doryrhamphus excisus* adapt relatively easily especially if live food is available. For others such as *Hippocampus kuda* or *Trachyramphus bicoarctatus,* management is more difficult because of their susceptibility to bacterial and viral attacks, especially in males (gas bubble disease). In contrast, management remains feasible and the aquarium is currently displaying fourth generation seahorses.

Mullidae such as *Parupeneus trifasciatus*, *P. indicus*, *P. rubescens* and *P. macronema* have caused problems; *Parupeneus cyclostomus,* however, adapts better to our conditions.

Of the complex families, some are no longer caught because of difficulties encountered with their management. This is the case with the families Dactylopteridae, Pempheridae, Diodontidae, Monacanthidae, Lethrinidae, Ostracidae, Siganidae and Ephippidae, which were only kept for a limited period at the aquarium (see Table 1).

As regards to the other families, a high degree of skill in capture and management techniques enables us to constantly improve our results. With Apogonidae (*Apogon apogonides*, *A. kallopterus* and *A. cookii*), the main problems observed were predation in the mixed tanks, but their management remains straightforward. Dasyatidae such as *Dasyatis violacea* adapt easily, while *Taeniura melanospilos* is more problematic, especially with parasites. With Aulostomidae (*Aulostomus chinensis*), management is complex because of their feeding habits and issues of interspecific territoriality. Fish in the Zanclidae family (*Zanclus cornutus*) are challenging because of their highly specific dietary needs. Management of a Sphyrnidae, *Sphyrna lewini*, for 18 months, was not difficult, but this specimen was accidentally wounded by another fish of the same species during feeding. This species remains, however, very difficult to manage, in particular around the time of capture and introduction into the mixed tank.

In order to remedy management difficulties met with some species, we directed capture activities towards post-larvae or juveniles, which adapt better to captivity than adults (Dufour 2002; Durville et al. 2003). This is the case for the families Monodactylidae, Serranidae, Carangidae, Microdesmidae, Pomacanthidae, Pomacentridae, Haemulidae and some Labridae. In addition, it is easier to catch younger specimens and so they experience less stress than do captured adults, which increases success rates. According to Wabnitz et al. (2003), this kind of capture, which affects only new recruits, also has less impact on coral reef fish populations already present on the reef.

Conclusion

This review of fish movements at the Reunion Island Aquarium shows 45.5% departures as compared with the total number of arrivals over a five-year period, with a significant drop in recent years (28.6% in 2000, down to 12.1% in 2004). These results take into account the first year of operations for the facility, which is a very difficult period because of the many biological, physical-chemical and technical factors that need to be mastered when a facility such as this is opened. The first year should, therefore, be considered as different from other years but it does yield important information on the development of an aquarium's opening population. Stress, diseases, territoriality and technical mishaps are all factors that limit the lifespan of fish in captivity. Their natural life expectancy should also be borne in mind. It is usually no more than a few years in coral reef fish (Froese and Pauly 2004), although greater longevity has been observed under farm conditions (Condé 1982).

This annual monitoring arrangement helped us gradually shift towards families seen as "easy" to manage under our conditions, thus reducing wild catch activities and associated costs. Of the "difficult" families, some really are difficult and remain so, while others are now understood and their survival rates have improved substantially. We believe that it is important for aquaria to optimize their stock management techniques as much as they possibly can by working on species that adapt to the conditions prevailing in their facility, rather than trying to show certain fragile species to the public at all costs. The recent development of coral reef fish nurseries will probably reinforce this trend and, in future, it will be possible to limit and control capture activities in the wild, gradually replacing specimens taken this way with species reared in captivity.

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