

**CREDIT SEMINAR
ON
FISH PHEROMONES AND THEIR POTENTIAL
APPLICATION IN FISHERIES**



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FISH PHEROMONES AND THEIR POTENTIAL APPLICATION IN FISHERIES

INTRODUCTION

Communication as action on the part of one organism (or cell) that alters the probability pattern of behaviour in another organism (or cell) in an adaptive fashion. By adaptive I mean that the signaling, or the response, or both have been genetically programmed to some extent by natural selection (Wilson, 1970).

Why fish need to communicate?

- To find prey
- To avoid predators
- To find mates
- To make schools / shoals
- To Find obstacles

How fish communicate?

- Visual cues - Eyes (Epipelagic fishes)
- Body Language (Behaviour) - CNS (Epipelagic fishes)
- Audible Sounds (Clicks or Croaks)
- Chemical Cues (Pheromone) - Gland (Bile and Skin)
- Sonic Cues - Muscle
- Electric Cues - Electric Organ

What are semiochemicals?

Semiochemicals are signaling chemicals that organisms can detect in its environment, which may modify its behaviour or its physiology.

Semiochemicals are classified into two main categories:

1. Allelochemicals

This term was proposed by Whittaker in 1970 and is used to describe chemicals that mediate interspecific interactions. Allelochemicals are classified into several subcategories:

- i. **Allomones:** Chemical substances that benefit the emitter but not the receiver (e.g. venom secreted by social wasps).
- ii. **Kairomones:** Chemical substances that benefits the receiver but not the emitter (e.g. host location by beneficial insects).
- iii. **Synomones:** Chemicals that mediate mutualistic interactions; benefits both the receiver and the emitter.

2. Pheromones:

The term pheromone was coined by Karlson and Luscher in 1959, for any substance secreted by an organism to the outside that causes specific reactions in the receiving organism of the same species.

Definitions:-

Pheromones are the molecules used for communication between animals. A broader term for chemicals involved in animal communication is semiochemical (from the Greek semeion sign) (Law & Regnier 1971). Strictly speaking, pheromones are a subclass of semiochemical, used for communication within the species (intraspecific chemical signals).

Pheromones (external hormones-ectohormones) are substances which, when released from fish into the aquatic environment, influence the behaviour of other individuals of the same species in general, and in particular the interaction between them, further to that mainly achieved by vision (Karlson and Luscher, 1959).

Karlson & Luscher (1959) first defined pheromones as "substances that are excreted to the outside by an individual and received by a second individual in which they release a specific reaction, for example a definite behaviour or developmental process".

The international term of pheromones is a compound word, from Greek Pheromone - "to bear" and hormone - "impetus".

Most species of fish rely on pheromones (chemical signals released by conspecifics) to mediate social behaviours.

Four groups of chemicals: i. Amino Acid, ii. Steroids, iii. Prostaglandins and iv. Bile Acids (and their derivatives)

Fish can detect even at minute (10^{-7} to 10^{-13}) concentration and each group of chemical have different receptors in the olfactory system (Hara, 1975). The use of released hormones (steroids, prostaglandins, and their metabolites) as sex pheromones is widespread among freshwater fishes.

Olfactory recordings and bioassays indicate such hormonal pheromone systems in three orders of ostariophysin fishes containing important cultured species: Cypriniformes (e.g. *Cyprinus carpio*), Siluriformes (e.g. *Clarias gariepinus*), Characiformes (e.g. *Colossoma spp.*). Similar evidence from Salmoniformes (*Salmo salar*), Perciformes (Family Cichlidae: *Haplochromis burtoni*; Family Gobiidae: *Neogobius melanostomus*), and Elopiformes (*Megalops cyprinoides*) raises the possibility of hormonal pheromones in marine species.

Mode of Pheromones Releasing by fishes:-

Pheromones are released into the aquatic environment either together with various biological excretions (urine, gonadal material, etc.) or from the cells of the

external surface of fish, in some of which this secretory activity is manifested only after their violent destruction.

Action of Pheromones:-

The action of pheromones may be described as the exchange of chemical signals which are received from the first cranial nerve of fish (olfactory nerve).

Three categories of pheromones can be discerned based on their function:

- i. Anti-predator cues (or) risk warning (alarm pheromones)
- ii. Social cues (or) behaviour between individuals of the same or other species (social behaviour pheromones)
- iii. Reproductive cues (or) sexual (reproductive) behaviour (sex pheromones).

Each of these categories comprises pheromones that can induce "primer" effects (developmental and/or endocrinological changes) and/or "releaser" effects (strong behavioural changes).

Properties of Pheromones:

Pheromone molecules used by aquatic animals are water-soluble and their diffusion rate can be 10,000 times lower than in the air. In the aquatic environment pheromones are further subjected to turbulence and variable flows. The use of water currents, natural or generated by the pheromone donors, amplifies the effectiveness of pheromone cues.

Pollution Disrupt the Communication Process:

However, the action of pheromone molecules can be altered or disrupted by other dissolved compounds such as humic acid, which can bind pheromone molecules or inhibit receptors (Hubbard et al. 2002), or by heavy metals that can disrupt the function of olfactory sensory neurons or cause degeneration of the olfactory system (Brown et al. 1982).

Impacts	Species	Toxicant	References
Erosion of the chemosensory organ	Yellow bullhead	Detergents (0.5 ppm)	Bardach et al. (1968) and Cangalon, 1983
Sexual-aggregating pheromones	Zebrafish	Zinc SL (0.5 ppm)	Bloom et al. (1978)
Depressed chemoattraction	Juvenile <i>Salvelinus fontinalis</i>	Linear alkylbenzene sulphate	(Olsen and Hogland, 1985).
Impaired of spawning migration	Salmons	Acidification of rivers	Hara, 1976b, 1992
Ovulated females significantly reduced	Male <i>S. salar</i>	Reduced at pH 5.5-4.5 and abolished at pH 3.5	Moore, 1994
Significantly reduced the ability of priming pheromone of ovulated females	Mature Atlantic salmon parr	Diazinon and Carbofuran (SL concentration)	Moore and Waring, 199th Waring and Moore, 1997
Depressive effects on the chemoreception	Salmonids	Ag, Hg, Cu and Cd	Hara and Thmpson (1978), Hara et at (1983) and Hara (1992)
Disrupts the reactions to	Zebrafish,	Zinc (Zn)	Bloom and

the sexual aggregating pheromonal communication			Perlmutter (1978)
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Functions of fish pheromones:

In order to find food, avoid predators and synchronize reproduction, animals must coordinate their life functions with environmental cues.

Chemoreception:

Four groups of chemicals such as i) amino acid, II) steroids, prostaglandins and bile acids (and their derivatives) have been found to be detected by the fish even at minutes (10^{-7} to 10^{-13}) concentration and each group of chemical have different receptors in the olfactory system (Hara, 1975).

Chemical analysis of Aquatic Fish Pheromones

In species where pheromones are not typical hormones, intensive chemical analyses have been productive in search of pheromone compounds. Such analyses usually involve exhaustive chromatographic and spectrometric methods including high performance liquid chromatography (HPLC), mass spectrometry (MS), and nuclear magnetic resonance (NMR) to concentrate, purify and identify compounds in water conditioned by mature animals, and to confirm the pheromone functions through EOG and/or behavioral tests.

- Solid phase extraction (SPE) is a method used to concentrate chemicals of interest from water for analysis.
- Liquid chromatography/mass spectrometry (LC/MS) is a rapidly evolving technique that is becoming more widespread in the analysis of fish pheromones, due to its high sensitivity and selectivity.

- ELISA is a type of immunoassay which uses competitive binding to antibodies to measure miniscule quantities of compounds, usually via a fluorescent label
- Electro-olfactogram (EOG) recording Measures olfactory sensitivity using extracellular recording of odor-induced changes in transepithelial voltage via an electrode placed near the surface of the olfactory epithelium and is thought to measure generator potentials of olfactory receptor neurons.

Types of Pheromones:

1. Aggregation pheromones

Its function in mate selection, overcoming host resistance by mass attack, and defense against predators. A group of individuals at one location is referred to as an aggregation, whether consisting of one sex or both sexes. Male-produced sex attractants have been called aggregation pheromones, because they usually result in the arrival of both sexes at a calling site and increase the density of conspecifics surrounding the pheromone source. Most sex pheromones are produced by the females; only a small percentage of sex attractants are produced by males

Examples

- Present of an aggregating pheromone has been implicated in schooling of the Marine Japanese Marine Catfish, (*Plotosus lineatus*) By Hayashi et al., 1994.
- Sexually aggregating pheromone system in the zebrafish may serve as reproductive isolation mechanism in the sympatrically breeding *Brachydanio rerio* and *Brachydanio albolineatus* (Bloom and Perlmutter, 1978)
- Teeter (1980) also hypothesized the involvement of pheromones in aggregating adult lampreys (*Petromyzon marinus*) prior to upstream movement or to keep them together in night during the migration.

2. Alarm Pheromones

Some species release a volatile substance when attacked by a predator that can trigger flight (in aphids) or aggression. In members of the same species i) use to alert others to a threat, ii) used as an alert to incoming predators.

Examples

- Von Frisch (1938) was first to discover the fright reaction in the European minnows (*Phoxinus phoxinus*). When a mechanically injured (physically damaged) fish was introduced to the school of minnows, all members became frightened, retreated and took refuge in a hidden place within 30s to 1 min. Later studies revealed that the skin contained the alarm substance (Substance d'alarme, schreckstoff) which elicited a fright reaction (reaction d'effort, schreckreaktion) among the minnows (von Frisch, 1941).
- Skin of ostariophysian, perciform, gonorhynchiform, salmoniform and other groups of fishes contains alarm substance cells (ASC) or sacciform cells. In ostariophysian fishes, the ASCs may constitute about 30% of the epidermis (Smith, 1986).
- Ultrastructural observations of the alarm substance cells of channel catfish revealed the presence of fish. These cells do not open directly to the surface of the skin but they release their contents only after a mechanical injury, presumably by a predator. As per adaptive significance of alarm pheromone is concerned, it is assumed that the alarm pheromone diffusing into the surrounding medium alerts and deters conspecifics from the spots, reducing the hunting success of the predators (Smith, 1977; Mathis et al., 1995).

- Interestingly, males of certain ostariophysian fishes with abrasive spawning behaviour lose alarm substance cells during breeding season due to elevated levels of androgen (testosterone) but they still retain the alarm reaction (Smith, 1973; Pfeiffer et al., 1985a).

3. Sex pheromone

In animals, sex pheromones indicate the availability of the female for breeding. Male animals may also emit pheromones that convey information about their species and genotype. The best known groups of pheromones in fish are sex pheromones which, in terms of chemical structure, can be free or conjugated to glucuronic acid steroids, C18, C19 and C21 sulphated steroids and prostaglandins. In animals, sex pheromones indicate the availability of the female for breeding. Male animals may also emit pheromones that convey information about their species and genotype.

Examples Female Sex Pheromones

- Salmonids males congregate around the cages/pens of the mature females during breeding seasons.
- Fisherman of Mississippi usually catch large number of male channel catfish, by placing ripe females in cages in the rivers (Timms and Kleerekoper, 1972).
- Water from gravid female seems to increase the nesting and other activities among males associated with reproduction in anabantids (Rossi, 1969) and cichlids (Cron de Caprona, 1974).
- A female sex pheromone appears to facilitate the pair formation and copulation in the marine carcharhinid shark (Johnson, 1978).

- Mature female sea lamprey, *petromyzon marinus*, release a pheromone in the ovarian fluid that attracts male conspecifics (Teeter, 1980).
- Mature female of goldfish, yellowfin baical sculpin, atlantic salmon, rainbow trout, common carp and *barilius bendelisis* released priming pheromone in the urine which enhances the plasma gonadotrophin (GtH) and testosterone (T) levels within 15-30 minutes and milt volume as well as sperm motility among males after prolonged exposure.
- Interestingly, mature female *Oreochromis niloticus* becomes attractive to male after 17,20-dihydroxy-4pregnen-3-one administration (Desouza et al., 1998).
- Urine of the female evoke maximum response in the conspecific males suggesting species-specificity of the pheromone (Kitamura and Ogata, 1989).
- Matsumura (1995) recorded tetrodotoxin as sex attractant pheromone to spermiating males in the marine puffer fish (*Fugu niphobles*)

Example Male Sex pheromones

- During breeding season, males become attractive to the female conspecifics.
- In some region of France, male lampreys nearing sexual maturity are placed by the fishermen in the traps to attract females (Fontaine, 1976)
- Lauman et al., (1974) recorded that the appendices of the 1st and 2nd anal fin spines of the mature male *Blennius pavo* produce a substance that attracts conspecific females.

4. Releaser

Releaser pheromones are pheromones that cause an alteration in the behavior of the recipient. For example, some organisms use powerful attractant

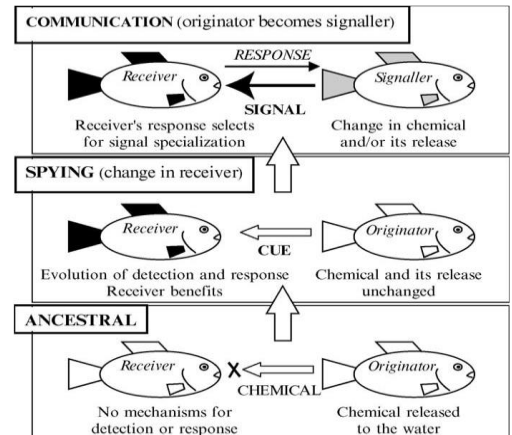
molecules to attract mates from a distance of two miles or more. In general, this type of pheromone elicits a rapid response, but is quickly degraded.

5. Signal

Signal pheromones cause short-term changes, such as the neurotransmitter release that activates a response.

6. Primer

Primer pheromones trigger a change of developmental events (in which they differ from all the other pheromones, which trigger a change in behavior).



Chemical communication Phases:

Its involves three functionally distinct phases:

- i. Ancestral
- ii. Spying and
- iii. Communication.

The initial phase, in which individuals (originators) fortuitously release a metabolic product(s) that does not influence receivers, can evolve into the second, spying, if selection causes conspecifics (receivers) to detect and respond adaptively to the originator's released chemical(s), which we now term a pheromonal cue(s). In the spying phase, originators remain unspecialized with respect to production and release of the pheromonal cue(s), regardless of whether they benefit from the receiver's response. In some instances, spying can develop into a third phase, communication, if originators also come to benefit from cue production, and develop specialization(s) to produce it in more effective manner(s). Such specialized cues are termed signals.

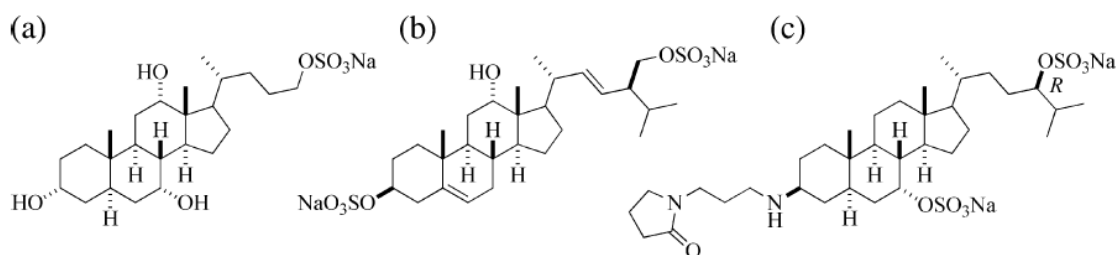
TABLE I. Continued

Compound	Species	Effect	References
Testosterone	Three spot gourami (<i>Trichogaster trichopterus</i>)	Unknown male effect	Becker <i>et al.</i> (1992)
	Yellowfin baikal sculpin (<i>Cottocomephorus grewingki</i>)	Elicit female spawning behaviour	Katsel <i>et al.</i> (1992)
Estrone	Round goby (<i>N. melanostomus</i>)	Increased ventilation rate in male	Murphy <i>et al.</i> (2001)
17 β -estradiol	Round goby (<i>N. melanostomus</i>)	Increased ventilation rate in male	Murphy <i>et al.</i> (2001)
Steroids conjugated Etiocholanolone (sulphated)	Round goby (<i>N. melanostomus</i>)	Female attractant (possible)	Arbuckle <i>et al.</i> (2005)
	African catfish (<i>Clarias gariepinus</i>)	Female attractant (possible)	Resink <i>et al.</i> (1989)
Etiocholanolone (glucuronidated) 17,20 β -P (sulphated)	Goldfish (<i>C. auratus</i>)	Elicit male sexual behaviour	Kobayashi <i>et al.</i> (2002)
	Rainbow trout (<i>O. mykiss</i>)	Unknown effect in males and females	Vermeirssen & Scott (1996)
17,20 β -P (glucuronidated)	Hill trout (<i>Barilius bendelisis</i>)	Male priming pheromone	Bhatt & Sajwan (2001)
	Rainbow trout (<i>O. mykiss</i>)	Unknown effect in males and females	Vermeirssen & Scott (1996)
	Roach (<i>R. rutilus</i>)	Unknown effect in males and females	Lower <i>et al.</i> (2004)
Dehydroepiandrosterone (glucuronidated)	Zebrafish (<i>Brachydanio rerio</i>)	Induces ovulation in females	Van Den Hurk & Resink (1992)
	Round goby (<i>N. melanostomus</i>)	Increased ventilation rate in males and females	Murphy <i>et al.</i> (2001)

Hormonal Pheromones in Fishes:

TABLE I. Known pheromone systems in freshwater fishes

Compound	Species	Effect	References
Prostaglandins Prostaglandin F _{2α}	Atlantic salmon (<i>Salmo salar</i>)	Male priming	Moore & Waring (1996)
	Arctic charr (<i>Salvelinus alpinus</i>)	Female attractant and elicit spawning behaviour	Sveinsson & Hara (1995)
	Brown trout (<i>Salmo trutta</i>)	Female prespawning behaviour	Laberge & Hara (2003)
	Goldfish (<i>Carassius auratus</i>)	Elicit male sexual behaviour	Kobayashi <i>et al.</i> (2002)
	Lake whitefish (<i>Coregonus clupeaformis</i>)	Increased locomotor activity in males and females	Laberge & Hara (2003)
13,14-dihydro-15- keto-prostaglandin F _{2α} (F _{2α} metabolite)	Cobitid loach (<i>Misgurnus anguillicaudatus</i>)	Elicits male sexual behaviour	Ogata <i>et al.</i> (1994)
	Brown trout (<i>S. trutta</i>)	Increased locomotor activity in males and females	Laberge & Hara (2003)
15-keto-prostaglandin F _{2α} (F _{2α} metabolite)	Goldfish (<i>C. auratus</i>)	Elicit male sexual behaviour	Kobayashi <i>et al.</i> (2002)
	Lake whitefish (<i>C. clupeaformis</i>)	Increased locomotor activity in males and females	Laberge & Hara (2003)
Steroids un-conjugated Etiocholanolone	Atlantic salmon (<i>S. salar</i>)	Male priming	Moore & Waring (1996)
	Round goby (<i>Neogobius melanostomus</i>)	Increased ventilation rate in males and females	Murphy <i>et al.</i> (2001)
11-ketotestosterone 17,20 β -P	Round goby (<i>N. melanostomus</i>)	Female attractant (possible)	Arbuckle <i>et al.</i> (2005)
	Rainbow trout (<i>Oncorhynchus mykiss</i>)	Female attractant (possible)	Arbuckle <i>et al.</i> (2005)
	Goldfish (<i>C. auratus</i>)	Unknown effect in male and female	Vermeirssen & Scott (1996)
	Roach (<i>Rutilus rutilus</i>)	Elicit male sexual behaviour and physiological priming	Kobayashi <i>et al.</i> (2002)
		Unknown effect in males and females	Lower <i>et al.</i> (2004)



The three primary components of the pheromone: (a) petromyzonol sulphate (PS), (b) petromyzosterol disulphate (PSDS) and (c) petromyzonamine disulphate (PADS).

Application of Fish Pheromones in Fisheries:

Use in control of both threatened (native) and unwanted (non-indigenous) fish species.

To control Invasive fish species

TABLE I. Continued

Compound	Species	Effect	References
Other			
7 α -12 α ,24-trihydroxy-5 α -cholan-3-one 24 sulphate (bile acid)	Sea lamprey (<i>Petromyzon marinus</i>)	Female sexual attractant	Li <i>et al.</i> (2002)
Petromyzonamine disulphate	Sea lamprey (<i>P. marinus</i>)	Component of migratory pheromone	Sorensen <i>et al.</i> (2005)
Petromyzosterol disulphate	Sea lamprey (<i>P. marinus</i>)	Component of migratory pheromone	Sorensen <i>et al.</i> (2005)
Petromyzonal sulphate	Sea lamprey (<i>P. marinus</i>)	Component of migratory pheromone	Sorensen <i>et al.</i> (2005)
Nitrogen oxide functional group	Ostariophysan fishes	Alarm cue	Brown <i>et al.</i> (2000)

The biodiversity of aquatic ecosystems is vulnerable to the introduction of non-native species (Sala *et al.*, 2000), posing a threat through predation of native species, resource competition, introduction of new diseases (Gozlan *et al.*, 2005) or alteration of the environment (Manchester & Bullock, 2000). Any technique that could help mitigate this problem is a potentially important tool in conservation. Pheromones play a vital role in the reproduction of some invasive species.

Chemo-attraction is the process of hijacking pheromone communication pathways between fishes, and using them to attract fish towards the fishing gear (Traps).

i) Sea Lamprey:

The sea lamprey is an ancient agnathan that finds its origins at the base of the vertebrate tree close to 400 million years ago (Forey & Janvier, 1993). This species, represent 40 lamprey species (Petromyzontidae) found in the Northern Hemisphere, is native to the Atlantic Ocean but has since invaded all of the Great Lakes and several of the Finger Lakes in North America (Smith & Tibbles, 1980; Bryan et al., 2005).

Introduced through the Erie Canal which opened in 1825. Improvements to the Welland Canal in 1919 are thought to have allowed its spread from Lake Ontario to Lake Erie, and while it was never abundant in either lake, it soon spread to Lake Michigan, Lake Huron, and Lake Superior, where it decimated indigenous fish populations in the 1930s and 1940s.

Impacts: They have created a problem with their aggressive parasitism on key predator species and game fish, such as lake trout, Lake Whitefish, chub, and lake herring. This could lead to a loss of biodiversity because of competition for resources in species such as mottled sculpin *Cottus bairdi* Girard (Dubs & Corkum, 1996) and egg predation in lake trout *Salvelinus namaycush* (Walbaum) (Chotkowski & Marsden, 1999) and lake sturgeon *Acipenser fulvescens* Rafinesque (Nichols et al., 2003).

Great Lakes Fishery Commission formed by the Convention on Great Lakes Fisheries, concluded in 1954 and ratified in 1955. Commission is charged, under Article Four of the Convention on Great Lakes Fisheries, with conducting research and making recommendations on the management of Great Lakes fisheries, as well attempting the eradication of the sea lamprey from the Great Lakes.

The North American Great Lakes *P. marinus* control programme has enjoyed success by the application of an integrated pest management (IPM) approach. The high fecundity of *P. marinus* and the damaging effect on native fishes has led to the search for more methods of control. Application of the recently discovered $7\alpha,12\alpha,24$ -trihydroxy- 5α -cholan-3-one 24-sulphate (3-keto-petromyzonal sulphate) (Li et al., 2002) may prove successful. This is an active component of a potent pheromone released by spermiating males that induces searching behaviour in ovulated females. As it is a bile acid and more water-soluble than steroids, it can be detected from a greater range (up to 65m; Li et al., 2002). This makes it an ideal candidate for use in IPM and could be used to trap mature females. Application could result in a shift in the sex ratio of the species causing severe competition for mates (Corkum, 2004). The success of a synthetic pheromone would of course be dependent on the cost of manufacture and the stability of the pheromone.

Research on Sea Lamprey: Researchers from Michigan State University have teamed up with others from the Universities of Minnesota, Guelph, and Wisconsin, as well as many others in a massive research effort into newly synthesized pheromones. These are believed to have independent influences on the sea lamprey behavior. US Gov. Despite millions of dollars put into research, however, the most effective control measures are still being undertaken by control agents of state and federal agencies, but involve the somewhat publicly unacceptable application of TFM into rivers.

TFM: Lampricide is a chemical which is designed to target the larvae of lampreys in river systems before their recruitment as parasitic adults. It is used in the headwaters of Lake Champlain and the Great Lakes to control sea lamprey

(*Petromyzon marinus*), an invasive species to these lakes. TFM (3-tri-fluoromethyl-4-nitrophenol) is the main chemical used for this purpose. As it is hydrophobic, it passes through biological membranes. The sea lamprey (*Petromyzon marinus*) is a parasitic lamprey found in the northern Atlantic Ocean along shores of Europe and North America, in the western Mediterranean Sea, and in the shores of the Great Lakes. This compound is presently employed, occasionally to kill larval sea lampreys in streams.

Pheromones have been used to successfully manage sea lamprey (*Petromyzon marinus L.*) in the American Great Lakes. Spermiating males were used as sexpheromone attractants in traps, which resulted in high captures of receptive (ovulating) females. In field conditions, 90% of actively migrating sea lampreys could be drawn into streams treated with a migratory pheromone.

ii) Carps:

The carp is considered an 'environmental engineer' and has inflicted large-scale damage to shallow water ecosystems, largely through its habit of digging in the bottom for food and uprooting vegetation (Weber & Brown 2009). This species is especially difficult to control because it is both long-lived and highly fecund, resilient yet highly mobile, and seemingly clever enough to learn and avoid nets (Bajer et al. 2010; Thwaites et al. 2010). Although large scale removal of aggregating carp is possible using radio-tag implanted carp ('Judas fish') to reveal the location of the aggregations (Inland Fisheries Service 2009; Bajer et al. submitted), this technique cannot be applied at all locations because of bottom structures. Furthermore, it is not easy to remove the low numbers of carp it can leave behind. Targeted trapping might be best for this and it could be improved by using specific designs (Schwartz 1986), locations (Thwaites et al. 2010), and baits which employ either food or sexual odours

(pheromones) (Sorensen & Stacey 2004). Pheromone induced trapping might also be useful to census populations of adult carp as part of integrated pest management schemes.

Five sex pheromones have now been identified in the carp, and all are mixtures which include hormonal derivatives. These 'hormonal pheromones' are detected with great specificity at low concentrations by mature carp (picomolar or grams in tens-to-hundreds of millions of litres of water) (Stacey & Sorensen 2009).

Case study 1: Carp pheromone attractant for carp control in NSW and Tasmania

Scientists at the University of Minnesota have been working on identifying carp pheromones and developing products containing these chemicals, which can be used to manipulate carp behaviour and potentially assist in controlling carp populations (Sorensen and Stacey, 2004). At least five sex pheromones have been characterised for carp: one is prostaglandin (a type of fatty acid), which is released by carp when they are ovulating and spawning.

Prostaglandin has been proposed as a lure to attract and trap sexually mature and receptive male carp (Lim and Sorensen, 2010). The Invasive Animals Cooperative Research Centre (IA CRC) funded research that found the male carp sex pheromone to be sex-specific and powerful. The research also found that ovulating female carp release a prostaglandin-based attractant for males and that non-ovulating females can be primed with a synthetic dose of prostaglandin to release the attractant. This synthetic prostaglandin can be implanted in a slow-release capsule in the fish, causing the female carp to produce their attractant pheromone for a longer period than usual (up to two weeks).

Trials: Pheromone technology is in the field, trials of pheromone attractants were conducted in Tasmania (Lake Crescent and Lake Sorell) and New South Wales (Lake Cargelligo and the Lachlan River). Tasmania was selected because of the expertise and infrastructure already invested in carp management in that state, especially the Integrated Carp Management (ICM) program that has been operating since 1995 in Lakes Sorell and Crescent. The NSW sites were selected because of the abundance of carp in that catchment and the existing resources dedicated to carp control.

Carp with artificially-inserted prostaglandin implants (called 'odour donors') were used to attract and trap feral (wild) carp in a series of experiments at Lake Sorell between October 2010 and January 2011. Field trials of pheromone attractant traps were conducted in Lake Cargelligo (September/October 2010 and September 2011) and the Lachlan River at Hillston (October/November 2010). A measured dosage of the pheromone (based on fish weight) was surgically implanted into female and male carp.

Result: The Lake Cargelligo trial, while successfully trapping over 6000 juvenile carp,

Partners and Management: IA CRC, Inland Fisheries Service (IFS) Tasmania, NSW Department of Primary Industries and the University of Minnesota.

Case study 2: Pheromone attractants as a means of carp control in Australian shallow lakes

Carp (*Cyprinus carpio*) are one of the most damaging invasive fishes in Australian shallow lakes, wetlands and rivers. Techniques currently available to control this species are generally labour intensive and unlikely to have long-term

benefits unless persisted with longterm. An important strategy for the control of carp is to enhance our understanding of their behaviours and vulnerabilities to improve the efficiency of control methods. For example, the success of existing control methods, such as trapping, can be increased by 'baiting' traps using various carp-attracting options. This factsheet explores chemical-based environmental and sensory attractants, which may potentially direct carp behaviour and movements.

These pheromones can be used in targeted trapping of other carp.

The use of pheromones to guide fish movement is still a relatively new concept, both in Australia and overseas. The development of selective carp pheromones holds promise as a tool for preventing carp population expansion and for population control. Pheromones enhance the effectiveness of carp trapping [Australian Broadcasting Corporation (2010)], but they could also possibly be used to disrupt carp movement and migration patterns, reduce their reproductive success, or to repel individuals.

Research by the University of Minnesota, funded by the Invasive Animals Cooperative Research Centre (IACRC), has found that common carp release at least three potentially useful pheromones:

- A male-derived pheromone which specifically attracts receptive females
- A female-derived pheromone which specifically attracts receptive males
- A species-identifying pheromone released by all carp, which compliments the other cues.

All of these pheromones can be concentrated and purified, so chemical identification and large-scale application should eventually be possible. The research found that

the optimal dose of PGF2 α for implantation is 0.4 g/kg of fish. At this dose, the implant is both cost-effective (~\$130/fish) and biologically potent.

Stimulation

Hormonal pheromone function is best understood in goldfish (*Carassius auratus*), in which studies of production, release, detection and biological response have demonstrated that males respond to two distinct pheromones released sequentially by ovulatory females. A preovulatory steroid pheromone (the MIS 17 α ,20 β -dihydroxy-progesterone [17,20--P] is the major component) increases male GTH-II, increasing the quantity and quality of releasible milt at spawning. A postovulatory prostaglandin pheromone triggers male courtship behaviors. These male responses to female ovulatory hormones appear to be similar in the related common carp (*C. carpio*) and Crucian carp (*Carassius carasius*).

Carp Pheromone Summary

- Pheromone technology is under development
- We need to learn more about pheromone characteristics and function.
- The use of pheromone has minimal impact on nontarget species.
- Pheromone may be species- and lifestage-specific.
- Pheromones might be useful in all types of flow conditions, however flow will influence the spread of pheromone.
- Although it is expensive to synthesise pheromone, only a small amount is needed.
- Pheromone is best used in combination with other control techniques such as traps and cages.

- When applied in conjunction with a trap or cage, captured fish need to be regularly removed and disposed of.
- A regular replenishment of pheromone supply is also needed.
- Public safety concerns are not yet known. Chemical use in water may be a concern for environmental protection authority and animal ethics and a risk assessment is required.

CURRENT TRENDS IN PHEROMONES RESEARCH:

Aquafeed attractants tested by Feedstuffs Reprint April 30 2007

- Pheromones, it seems, can attract more than a mate at least in fish. These chemical signals can trigger heightened responses relating to shoaling, reproduction, migration and feeding behavior.
- Following successful laboratory results to assess the efficacy of pheromone-based feeding attractants in full-scale commercial situations, the U.K. government agency Centre for Environment, Fisheries & Aquaculture Science (CEFAS) has conducted trials in partnership with Kiotech International and local aquaculture and fish institutes in China and Thailand.
- These attractants are currently distributed worldwide in more than 42 countries and are, it seems, contributing to both the capture of record and trophy fish and, indeed, to increasing the overall success of individual fishermen.
- However, it is now becoming apparent that this pheromone technology has much wider applications, particularly in improving the efficiency and sustainability of the worldwide aquaculture industry. The development of the pheromone technology now has two principal objectives.

- First, it will increase the feeding activity of farmed fish and, therefore, the uptake of feeds. This should lead to an increase in the growth of fish and a reduction in the amount of waste from uneaten feed, which results in additional costs to the fish farmer and significant environmental damage.
- The second, and longer-term, objective is that pheromone-based technology will be used to enable the use of more sustainable forms of proteins within feeds, which are not based on fish oils or proteins. This approach will further conserve and protect the wild fish populations and help provide a sustainable base for the large-scale expansion of the aquaculture sector.
- Dr. Andrew Moore, head of salmon and freshwater fisheries at CEFAS, will present the results of recent commercial trials that were conducted with tilapia and trout in Zhouhai, China, and with white shrimp in southeast Thailand, at next month's Aquafeed Horizons Conference to be held alongside Victam International in Utrecht, Netherlands.
- They will demonstrate that the application of the pheromone-based product Aquatice produced a 17% increase in the average weight of the tilapia and 30% in shrimp. In the case of tilapia, the farmers started harvesting three weeks earlier and saw significantly faster growth, and the farmers received 50% higher income. For white shrimp, they recorded significantly faster growth and had a lower food conversion rate.
- As a result of these trials, CEFAS and Kiotech foresee the potential for significant commercial benefits to farmers operating in the global aquaculture market as well as producing equally important environmental benefits.

Pheromone based fish attractant in Markers of US and UK

BARBEL SCIENCE Organic Pheromone Fishing Bait Additive / Attractant by VandaRoseAroma - \$10.75 (Rs.738) (United Kingdom)

BASS SCIENCE Organic Pheromone Fishing Bait Additive / Attractant - \$10.75

BREAM SCIENCE Organic Pheromone Fishing Bait Additive / Attractant - \$10.75

CARP SCIENCE Organic Pheromone Fishing Bait Additive / Attractant - \$10.75+

CATFISH SCIENCE Organic Pheromone Fishing Bait Additive / Attractant \$10.75+

CHUB SCIENCE Organic Pheromone Fishing Bait Additive / Attractant \$10.75

SALMON SCIENCE Organic Pheromone Fishing Bait Additive / Attractant \$10.75+

PIKE SCIENCE Organic Pheromone Fishing Bait Additive / Attractant \$10.75+

SEA FISH SCIENCE Organic Pheromone Fishing Bait Additive / Attractant \$10.75+

SHARK SCIENCE Organic Pheromone Fishing Bait Additive / Attractant \$10.75+

TENCH SCIENCE Organic Pheromone Fishing Bait Additive / Attractant \$10.75+

TROUT SCIENCE Organic Pheromone Fishing Bait Additive / Attractant \$10.75+

Fish Pheromone Bait additive Collection, 5 x 10ml Blended Organic Essential / Carrier Oil Blends PACK 2 - \$41.44 (Rs.2848)

Fish Pheromone Bait additive Collection, 5 x 10ml Blended Organic Essential / Carrier Oil Blends PACK 1 \$41.44+

New Baitmate Classic Bass Concentrated Pheromonebased Fish Attractant US \$4.99 (Rs. 342)(USA)

New Baitmate Classic Crappie and Panfish Pheromonebased Fish Attractant 528W US \$4.99

Pheromone bait for carp SUPER AIT CARP. Activatorattractant fishing for carp. US \$6.85 (Rs.470)(Item location: Belarus, Belarus)

PHEROBASE

Pherobase is a freely accessible database of pheromones and semiochemicals. It comprises several databases to provide comprehensive information about pheromones and semiochemicals. The main objective of The Pherobase is to convert scientific data and knowledge from the literature and convert the peer-reviewed information about behaviour-modifying chemicals into an electronically searchable database. The Pherobase covers most animal orders and all types of semiochemicals. In addition to sex pheromones, you will find all other categories of semiochemicals. The coverage ranges from invertebrates to vertebrates, and thousands of plant species.

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